Evaluation of Work Sampling as an Indicator of Construction Labor Productivity

by

Muhammad Ali Mubarak Al-Ghamdi

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

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This thesis, written by **MUHAMMAD ALI MUBARAK AL-GHAMDI** under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of the College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT.**

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25 · 6 · 95

Date

This thesis is dedicated to my beloved

Father, Mother, Brother and Sisters

for their continuous support and encouragement

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I am most grateful to Almighty, ALLAH, who gave me the well and power to accomplish this work.

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خلاصة الرسالة

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التخصص : هندسة وادارة التشييد

التاريخ : محرم ١٤١٦هـ

تهدف هذه الرسالة الى تقييم قدرة استخدام عينات العمل في تقدير انتاجية عمال التشييد آخذة بعين الاعتبار تاثير مستوى تعقيد العمل، عدد العمال، و مستوى المهارة على العلاقة بين الانتاجية و نوع عينة العمل. في هذه الدراسة تم اختبار الثلاث فرضيات التالية، تزداد الانتاجية بازدياد العمل الفعال، تزداد الانتاجية بنقصان العمل اللافعال، يزداد العمل الفعال بنقصان العمل اللافعال.

تم في هذه الدراسة اجراء وتصوير ٣٥ تجربة ميدانية لبناء جدران استخدم في بنائها ثلاثة مستويات من الصعوبة، حجمان من فرق العمل، و مستويان من المهارة.

اظهرت النتائج أن الفرضيات الثلاثة صحيحة. كما أظهرت أنه لايوجد تاثير واضح لمستويي الصعوبة و المهارة على العلاقات المنصوصة في الفرضيات السابقة، و لكنها أظهرت أن العلاقات الثلاثة تتاثر بحجم فرقة العمل. بالرغم من أن النتائج أظهرت أن العلاقات الثلاثة صحيحة، فانها تشير الى أن عينة العمل ليست مؤشرا دقيقا لأنتاجية عمال التشييد.

درجة الماجستير في العلوم
جامعة الملك فهد للبترول والمعادن
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THESIS ABSTRACT

Name: **Muhammad Ali Mubarak Al-Ghamdi**

Thesis Title: **Evaluation Of Work Sampling As An Indicator Of Construction Labor Productivity**

Major: **Construction Engineering And Management**

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This thesis evaluates the use of work sampling in predicting construction labor productivity. It also considers the effect of complexity level, crew size, and skill level on the relationship between productivity and work sampling categories. This study tests three hypotheses: productivity increases as the effective work category increases, productivity increases as the ineffective work category decreases, and effective work category increases as the ineffective work category decreases.

A total of 35 field experiments of walls building were performed and filmed in this study. For these experiments, three complexity levels, two crew sizes, and two skill levels were considered.

The results show that the three hypotheses are true. They also indicate that complexity and skill levels have no significant effect on the relationships advanced in the above hypotheses, but the three relationships are affected by the crew size. In spite of the support of the above hypotheses, the results indicate that work sampling is not a very strong predictor of construction labor productivity.

MASTER OF SCIENCE DEGREE

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DHAHRAN, SAUDI ARABIA

CHAPTER 1

INTRODUCTION

Productivity is one of the measures that is frequently needed in construction industry. Productivity provides significant information needed for the improvement of planning, scheduling, and control of the work.

Construction productivity is a general term that applied for labor, and equipment. However, the main concern in this study is with the measurement of construction labor productivity. There are many different techniques that can measure construction labor productivity, and one of these techniques is work sampling. Although it does not provide a direct measure of labor productivity, work sampling can indicate construction labor productivity. By relating the work sampling categories to their corresponding productivity, work sampling categories of another work can predict the labor productivity of that work. This technique has been used for a long period of time, and there are many studies that support the accuracy of using work sampling in the measurement of construction labor productivity.

However, the results of one study (Thomas, 1991), have casted significant doubts on the validity of work sampling in measuring labor productivity. This study suggests that there is no relation between work sampling categories and the corresponding actual productivity. In this study, different crafts were examined, and none of them showed a

positive correlation. In fact, this study came up with a strong statement concluding that "direct work can not be used to predict labor productivity "(Thomas, 1991, p. 443).

The contradiction over the validity of work sampling attracted the attention of the researcher. Most of the studies made on this subject were investigated by the researcher. This helped the researcher in developing the methodology of this study. In this study, 35 field experiments of wall construction were performed, and filmed by a video camera. Then, the data gathered from these experiments were analyzed and the results of the relationship between productivity and work sampling, were presented.

1.1 Purpose Of The Study

The main purpose of this study is to test the validity of using work sampling as an indicator of construction labor productivity. In addition, this study is going to investigate the effect of some of the task characteristics, which are complexity level, crew size, and skill level, on the relationship between labor productivity and work sampling categories.

1.2 Significance Of The Study

This study has a great significance because of the following two main reasons; The value of the problem investigated by the study, and the approach that was designed to achieve the study objectives.

The main significance of the study is that it will help to resolve the contradiction of previous studies over the validity of work sampling as a predictor of productivity. Also, it will provide a better understanding over the limitations, and assumptions of using work sampling as an indicator of labor productivity.

In addition, the use of field experiments added to the significance of the study. This approach, which has not been utilized in any reputed work sampling studies, helped in providing accurate data that satisfied the purpose of the study, and provided better control over the influencing variables, which are complexity level, crew size, and skill level.

CHAPTER 2

REVIEW OF LITERATURE

In this chapter a brief review of productivity and work sampling will be presented. In addition, it will review some of the studies that investigated the validity of work sampling in measuring productivity.

2.1 Productivity

2.1.1 Definition Of Productivity

Although it has a number of meanings, the term *productivity* expresses the relationship between outputs and inputs (Liou, Borcherding, 1986). The following model represents this relationship,

$$productivity = \frac{Outputs}{Inputs} \qquad (1)$$

This is a general model of productivity. The outputs and inputs differ from one industry to another. Also, productivity definition varies with the application within the different areas of the same industry. For example, in the construction industry, there is a need for using different models, such as, The Economical Model, The Project Specific Model, and The Activity Oriented Model (Thomas, et al, 1990). These models are:

The Economical Model

$$productivity = \frac{Dollars\ of\ Output}{Dollars\ of\ Inputs} \quad (2)$$

The Project Specific Model

$$productivity = \frac{Square\ Feet\ Output}{Dollars\ of\ Input} \quad (3)$$

The Activity Oriented Model

$$productivity = \frac{Output}{Labor\text{–}Cost\ or\ Work\text{–}Hours} \quad (4)$$

However, in the construction industry, the main concern is with labor productivity. Because, construction is mainly dependent on the manpower needed to finish a specific task. Labor productivity usually relates manpower, in terms of man-hour or labor cost, to the unit of outputs produced (Liou, Borcherding, 1986). So, labor productivity indicates the efficiency by which the output of goods and services produced in a time frame by a production factor, that is manpower (Adam, Hershauer, Ruch, 1981). In other words, the definition of labor productivity is the amount of goods and services produced by a productive factor (manpower) in a unit of time (Drewin, 1982).

2.1.2 Importance Of Productivity

Productivity has a great significance in construction. As mentioned previously, the work in construction industry is heavily dependent on the work force. So, labor productivity constitutes a major share of production input in construction. In the construction industry, there are many external and internal factors that are never constant and difficult to be anticipated. These factor will lead to a continuos variation in labor productivity. It is important to make sure that the reduction in productivity does not affect the plan and schedule of the work and does not cause delays. The consequences of these delays could be developed into great money losses.

On the other hand, much money saving can be made if productivity is improved. This is because the same work can be produced by less manpower resulting in less labor cost, that has been rising since 1971 (Thomas, 1981). Also, the quality of workers can be improved in the long run (Liou, and Borcherding, 1986).

Generally, better control of any construction project could be made, if accurate and frequent measures of productivity were obtained. The faster the information is obtained the earlier the corrective action could be made. In the next section different techniques of measuring productivity are presented.

2.1.3 Measurement Of Work Sampling

Productivity needs to be measured on a continuous basis to monitor the work

and make the necessary corrective actions. So, there is a need to have a simple, fast, and accurate method for the measurement (Liou, Borcherding, 1986).

There are different ways by which productivity can be measured. One of these methods is the unit rate which is represented as;

$$productivity = \frac{\text{Production factor per unit time}}{\text{Goods and services produced}} \quad (5)$$

Although the unit rate is the most objective and direct measure of labor productivity in construction and it has been used for years as productivity index, it does not have the ability of providing fast results (Liou, Borcherding, 1986). Examples of other techniques used to measure construction labor productivity include five minute rating, productivity ratings, and field ratings (Logcher, and collins, 1978).

However, among all the techniques used for the measurement of productivity, Work sampling is the most preferred because of the positive features it has (Drewin, 1982). Work sampling is presented in great details in the following section.

2.2 Work Sampling

Around 1927, work sampling was first introduced by L. H. C. Tippet. It was used in the English Textile Industry. It was first named by Tippet as the *snap reading method* after the snapshot concept of photography. Then around 1935, the name was changed by Professor Robert Lee Morrow to the *ratio delay technique* (Drewin, 1982).

The name *work sampling* was first given by C. L. Brisley in 1952. No changes in the name had been made since that date, because it is more descriptive than the previous two names and can cover more general uses of this technique (Drewin, 1982).

2.2.1 Definition Of Work Sampling

An appropriate definition of work sampling is needed to describe fields of application. The American Institute of Industrial Engineers official definition of work sampling is;

"The application of statistical sampling theory and technique to the study of work systems in order to estimate universe parameters from sample data. It is commonly used in the work measurement and methods engineering area to produce statistically sound estimates of the percentages of time that a work system is in any of a variety of states of work activities. With appropriate procedures, work sampling can produce information from which time standards might be determined", (Liou, Borcherding, 1986, P.92).

The technique of work sampling can be used to facilitate quantitative analysis in terms of time of the activities of workers, machines, or processes (Liou, Borcherding, 1986).

2.2.2 Advantages Of Work Sampling

Work sampling became a preferred technique because of the different appealing benefits it provides (Thomas, Holland, 1980). Some of these are;

1. It can be utilized as an indicator of labor productivity (Liou, Borcherding, 1986).

2. It gives an overall picture of the distribution of activities of workers and machines

(Thomas, Holland, 1980).

3. It involves the first line of supervisors (Richardson, 1976).

4. It is particularly appropriate for the analysis of indirect labor (Richardson, 1976).

5. It posses known statistical reliability (Thomas, Holland, 1980).

6. It is relatively simple, easily understood technique (Thomas, Holland, 1980).

7. It is relatively inexpensive and can be done in an economical way (Drewin, 1982).

8. Work sampling focuses on the individual rather than the crew, which is the basic construction unit (Thomas, Maloney, Horner, Smith, Handa, Sanders, 1990).

9. No special equipment is required to conduct the study (Drewin, 1982).

10. Results are available quickly (Drewin, 1982).

11. It does not require many observers, one observer can study several workers and machines at the same time (Drewin, 1982).

12. Interruptions of the study can be tolerated (Drewin, 1982).

2.2.3 Disadvantages Of Work Sampling

On the other hand, some of the drawbacks are;

1. Work sampling data are not as detailed as data collected by other methods (Thomas,1981).

2. It is not an economical method for the study of a single machine or worker (Drewin,1982).

3. It is not well suited for sampling on short cycle jobs (Drewin, 1982).

4. It is not a direct measure of labor productivity (Richardson, 1976).

5. It does not include the basic information measure for individual method improvement (Thomas, Holland, 1980).

2.2.4 Data Collection In Work Sampling

The data collection process for work sampling studies requires the knowledge of the following, data collection approaches, observations, and categories. In this section the trade off between the main two approaches, the proper selection of categories, and general rules of taking observations will be discussed.

2.2.4.1 Approaches

One of the positive characteristics of work sampling is that it can be used to focus on either the effectiveness of the overall site or that of a specific crew (Liou, Borcherding, 1986). This flexibility is due to the availability of two main options of data collection of work sampling. These are known as the tour approach and the crew approach (Thomas, 1981). For different situations, the selection of a suitable approach requires a good understanding of the positive and negative features of each approach.

The tour approach is used by the management to give a general survey of the work of the whole project. In this approach, random routes are usually identified through the entire work location to be used by the observer during the data collection process. The

observer walks during his tour at a predetermined random time and records the activities of all the craftsmen in view. So, this approach requires the observer to be physically fit to follow the planned routes a number of times for each study. Also, the observer should have the ability of recognizing the workers during his tour. Generally, this is considered as the major disadvantage of this approach (Thomas, 1981). If the observer lacks this ability, statistical deficiencies may be caused due to workers crossover from one area to another and worker absence from an assigned work location (Thomas, Holland, 1980).

So, more attention is required by the observer to recognize the workers. Other than that, this approach will help to increase the coverage of the study and will give a general view of the work performance.

The crew approach can be applied in different types of studies, such as field experiments, at which the focus is on a specific crew. This approach will make it easier for the observer to recognize the workers during the study. Although, using this approach will help in avoiding the problems of crossover or absence of workers, it is not designed to cover the whole project area.

The use of the crew approach can have several benefits. It permits the study to focus on critical activities, it can provide much more descriptive data, and it can help to identify difficulties faced by craftsmen. However, there are two main disadvantages of the crew approach. First, it is less economical because observations are taken for less number of workers. So, more time is needed to collect the data. The second disadvantage is that using this approach may cause an adverse response by the workers. This adverse response may make the workers to develop a mechanism for alerting each other to change

their ways of working when the observer is present, leading to wrong observations and false information (Thomas, 1981). So, the observer should consider this problem when taking observations.

So, none of the two approaches is perfect, and management must weigh the tradeoffs between them to have the proper selection. The major tradeoff will be mainly between the increased coverage (tour) and the increased detail (crew). In addition, the drawbacks of each approach should be considered with the objectives of the work sampling study.

2.2.4.2 Observations

Regardless of the approach used for data collection, observations are made based on specific work categories. From the proportions of observations in each category, inferences are drawn concerning the total work activity under study (Richardson, 1976). The prediction accuracy of any sampling depends heavily on the way observations were made (Oglesby, Parker, Howell, 1989).

The accuracy of the observations depends mainly on the observer. The accuracy can be affected greatly by human limitations, observer fatigue, and variations between observers. Human limitations are mainly due to the inability of the observer to cover all assigned areas uniformly, the observer cannot determine the exact nature of the work at a precise instance, and that the observer can not look into every place on the project.

Another important issue that should not be neglected by the observer is that sampling activities should not be secretive. The observer should be encouraged to be open and communicative with the craftsmen and their supervisors (Thomas, Holland, Gustenhoven, 1982). This will help avoid any abnormal worker behavior caused by the presence of the observer (Oglesby, Parker, Howell, 1989). The behavior of a worker will be affected by several factors including the confidence of the worker in the sincerity and integrity of management, his age, the way the work study was introduced, and whether the observer uses timing devices or special forms (Drewin, 1982).

In addition, it is very important to make sure that observations are taken randomly. In order to ascertain randomness, each element has to have an equal chance of being selected, and selection is independent of the previous selections. Also, selection of an element is made when it is first seen. In addition, the basic characteristics of sampling situation remain unchanged during the time of observations (Drewin, 1982).

Observation bias is one of the errors made in work sampling. This error can be eliminated by better understanding of the main points of the previous discussion.

2.2.4.3 Categories

In work sampling the term *Category* is used to contain all the observations of similar classification to be grouped together. The categories are usually predefined by the management or the work sampling team. Categories definition is a very important task that should be made with great care. The accuracy of any work sampling study can be

affected by not having a proper definition of the categories. It is helpful to consider the following two questions when defining work categories, "Do the categories enhance the accomplishment of the work sampling program objectives?", and "Do the categories provide the manager with the type of information needed in order to take appropriate action?", (Thomas, and Holland, 1980, p.522).

One of the important criteria for having a good definition of the work categories is to select categories that are compatible with the work sampling study objectives. The compatibility will help to achieve the goals of the study. Another important point is the degree of details required by the study. The more the work is broken down into activities, the more the number of categories used. So, this will help to increase the degree of details of the study, which will help to provide more descriptive information. In addition, there should be consistency in the definition of categories, especially when the results of the study are going to be used for comparison across projects.

For preliminary studies of work sampling, three main categories are usually used. These categories are *Effective Work*, *Essential Contributory Work*, and *Ineffective Work* (Thomas, 1981).

Categories' selection is an important task, and it can be considered as the key for reliable results.

2.2.5 Data Analysis

The data analysis in work sampling depends on the objectives of the study.

Generally, the basic use of work sampling data is to review the percentages of the concerning categories to find weather they are unusually high or low.

However, further analysis is needed for other uses of work sampling. One example is when work sampling is used to predict productivity. In this case, work sampling percentages are related to productivity. Then, productivity can be predicted by studying the variation in these percentages.

2.3 Validity Of Work Sampling

It is widely recognized that construction productivity is particularly difficult to measure (Thomas, Holland, 1980). Although methods such as the unit rate formula can be used, work sampling is the most suitable because of the positive features presented in section 2.2.2. Work sampling is utilized by first relating the percentages of categories of a work sampling study with the measurement of productivity to give what is called a "bench mark" or a reference. Then, based on this relationship the change in productivity will be indicated by another work sampling study. This will provide management with fast and valuable information, on which future actions can be based.

The validity of work sampling had been tested by many studies. Most of them showed that there is a strong positive correlation between direct work percentages and productivity. Examples of these studies are; Liou and Borcherding (1986), Thomas (1984), and Handa and Abdalla (1989). However, the validity of these studies had been questioned by Thomas (1991) on three grounds. First, the craftsmen were studied for

works unrelated to their crafts. Second, time frames of work sampling studies and their corresponding unit rates were not the same. Finally, some of the conclusions are not realistic. So, based on these deficiencies in the previous studies, he made his study for evaluating the validity of work sampling.

The study of Thomas (1991) has a great value, because it reviewed seven data bases. An example of these data bases is the Thirty - Project Data Base that contained more than 158 work sampling studies covering various crafts in 30 construction projects for the period from 1977 to 1985. The study examined three basic assumptions. "First, reducing the amount of time spent waiting leads to more time spent in direct work activities. Secondly, if more time is spent in direct work activities, the productivity will be better. Finally, if the first two assumptions are true, it follows that reducing waiting time will lead to improved productivity", (Thomas, 1991, p.435). The study came up with a surprising conclusion, it states that work sampling has no relationship with productivity.

However, there are several weaknesses that can be observed in the above Thomas' study. First, the work sampling data was mainly collected from previous studies. This may be considered as a source of variation because these studies had different observers, objectives, and categories. Second, the productivity is represented by the performance factor that its calculation is based on relating the estimated unit rate to the actual one. Different unit rate estimates from different studies were used. So, the calculation of the performance factor may not be so accurate, because it depends on the accuracy of unit rate estimate. Finally, the work of craftsmen from which the data collection for the work sampling studies is not well defined. There is nothing mentioned about whether the work

done by certain craft is of the same work nature or not. So, it was not clear and it can be considered as a major source of error because even for the same craft the work can have different characteristics.

In addition, Thomas presented in his study some of the factors that can affect the relationship between productivity and work sampling percentages especially direct work category. These factors are grouped under Project Characteristics and Work Sampling Study Procedures. Examples of the project characteristics are complexity level, crew size, and skill level. These factors are varying greatly in construction, depending on the project size, scope of work, and work schedule. Likewise, each researcher had his own procedure of work sampling that was used in his study. So, Thomas questioned the influence of these factors on the relationship between work sampling and productivity.

However, despite these weaknesses, Thomas' conclusions remain strong and worth further investigation.

CHAPTER 3

METHODOLOGY

3.1 Objective

The basic objective of this study is to test the relationship between productivity and the percentages of work sampling categories, and to assess the effect of selected influencing variables on this relationship. This chapter presents the hypotheses, the influencing variables, and the study design utilized in meeting the above objective.

3.2 Hypotheses

The hypotheses tested in this study are derived from the above objective and from the three assumptions challenged by the study of Thomas (1991). These hypotheses are,

1. The time spent on effective work (EW) is positively related to productivity (Pr). The greater the time spent on effective work, the greater the productivity, and vice versa.

This was tested by using the coefficient of correlation (r) of effective work and productivity. If the coefficient of correlation was found to be greater than zero then the hypothesis is true. Stated symbolically, the null hypothesis is;

H_o: $r_{EW,Pr} > 0$

2. The time spent in ineffective work (IW) is negatively related to productivity (Pr). The lesser the time spent on ineffective work, the greater the productivity, and vice versa.

This was also tested using the coefficient of correlation (r) of ineffective work and productivity. If the coefficient of correlation was found to be less than zero, then the hypothesis is true. Stated symbolically, the null hypothesis is;

H_o: $r_{IW,\mathrm{Pr}} < 0$

3. The time spent in effective work (EW) is negatively related to that of the ineffective work (IW). The lesser the time spent on effective work, the greater the time spent on ineffective work, and vice versa.

The coefficient of correlation (r) was utilized to test this hypothesis. If the coefficient of correlation between EW and IW was found to be less than zero then the hypothesis is true. Stated symbolically, the null hypothesis is,

H_o: $r_{EW,IW} < 0$

3.3 Influencing Variables

In addition to the above, this study covered the effect of complexity level, crew size, and skill level over the results of testing the previously mentioned hypotheses. The operation selected for this study is masonry.

3.3.1 Complexity Level

In order to help in identifying the sources of complexity in masonry, that is the operation selected for this study, two highly qualified masons and a civil engineer, were consulted. They pointed out that curving walls is the most difficult. Also, the corners and intersection of walls need more care. Also, they suggested the use of blocks of (20 cm X 20 cm X 40 cm) dimension and running bond in the construction of the walls. These are the most common block size and joints' type used in construction in Saudi Arabia.

So, based on the above reasons, three complexity levels were designed. The first level of complexity (type-I)is the one shown in Figure 3.1. The figure shows that this is a simple straight wall. The design of this wall required 56 blocks. The second level of complexity (type-II) that is shown in Figure 3.2, represents a straight wall with two intersections of walls. This wall needed 63 blocks to build. Figure 3.3 shows the high complexity level (type-III). This shows a straight wall with two intersections of walls and two corners. Seventy blocks were required to build this wall. The dimensions of all the walls were governed by the work location available and the filming requirements.

In the designs of the three complexity levels, the choice of curved walls was not considered. This is because many concrete blocks are going to be wasted. So, in order to save time and money needed for materials and transportation, only the above three designs of walls were considered.

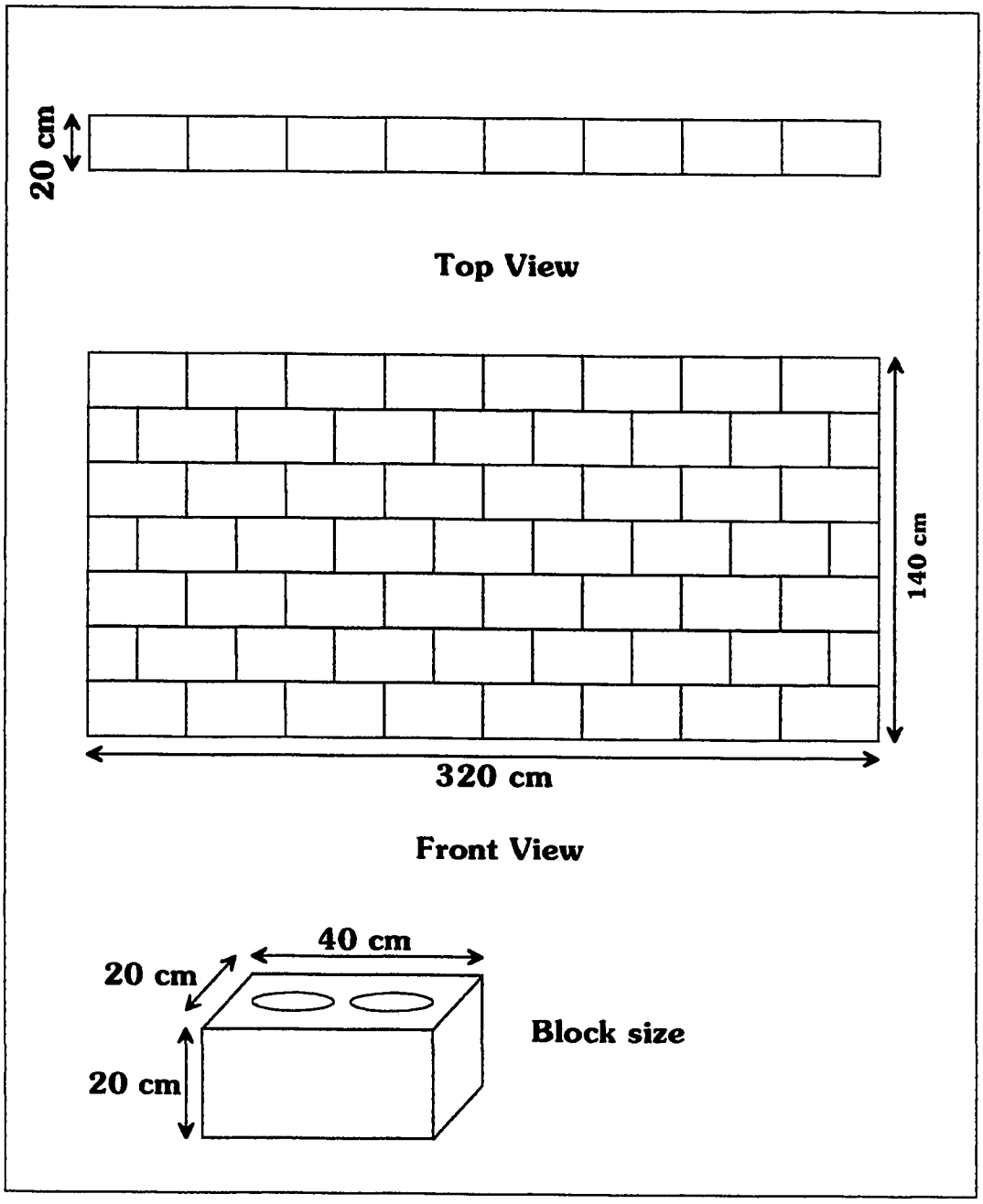

Figure 3.1 - Wall Design Of Simple Complexity Level

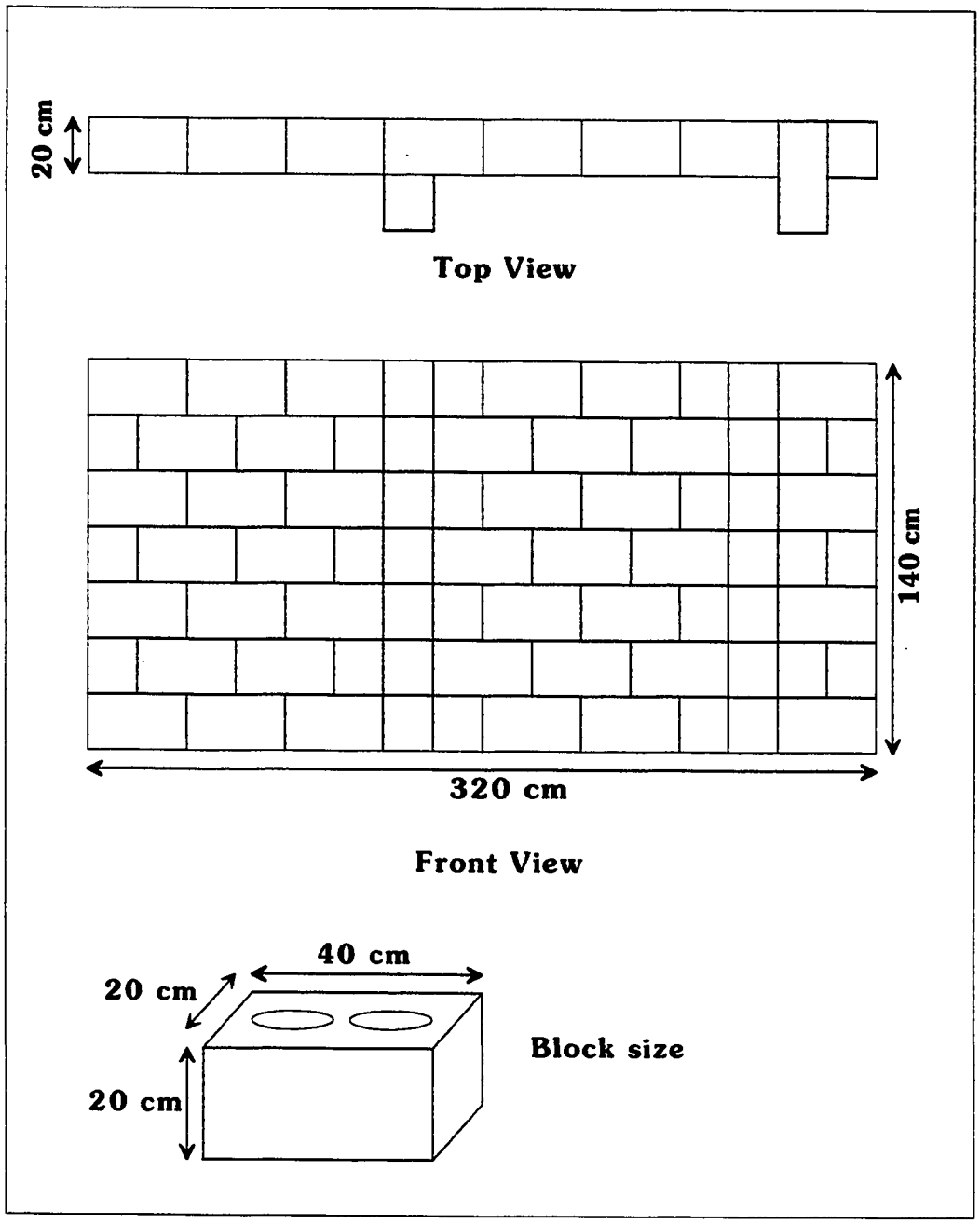

Figure 3.2 - Wall Design Of Moderate Complexity Level

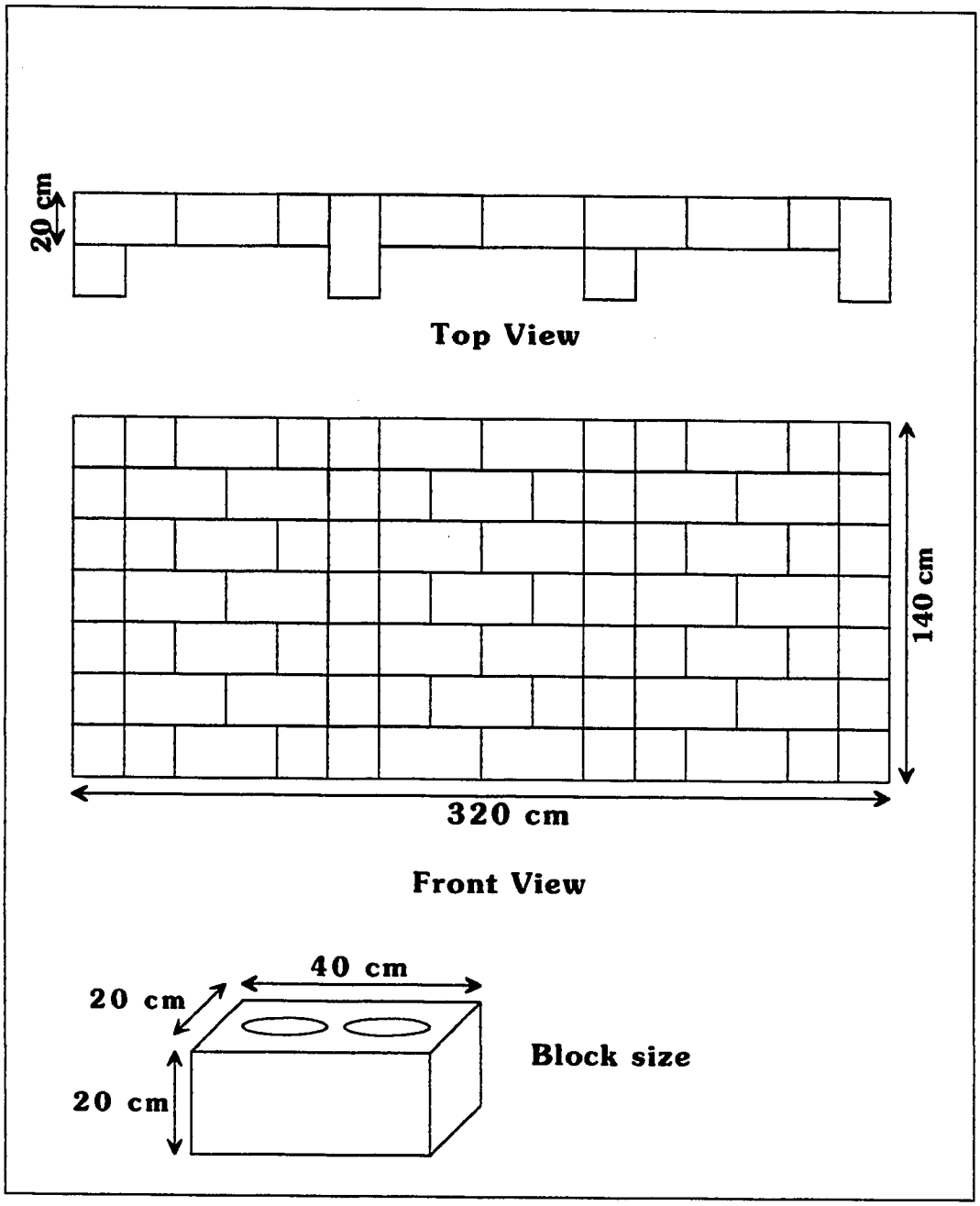

Figure 3.3 - Wall Design Of High Complexity Level

3.3.2 Crew Size

In this study, the workers of MUAN Company, which is a company specialized in telecommunication in the eastern province of Saudi Arabia, were used. Though there was a great cooperation by MUAN, the maximum number of workers allowed to participate in this study was four. So, only two crew sizes were considered in testing the effect of change the number of workers on the relationship between work sampling and productivity. The first one has two workers and the other has four workers.

3.3.3 Skill Level

An evaluation of the workers and their skills was performed by their Foreman. The foreman was asked by the researcher to evaluate his workers on a scale of ten. The scores of his evaluation ranged from five to nine. Most of the scores were either five or nine. So, two skill levels were considered one with a score of five and the other with a score of nine. The one with five was considered as low skill level and the one with nine was considered as high skill level.

3.3.4 Quality Level

Although there are two skill levels, a mockup was built to represent the quality of work that should be met by the workers. The building of the mockup was to make sure that a certain level of quality will be maintained. This helped in eliminating the variability

of quality.

3.4 Study Design

In this study, the data was gathered by field experiments. This was considered to provide accurate and reliable data that will help in achieving the objectives of the study and will provide better control of all the influencing variables. In this study, five groups of data with different combinations of these variables were considered. The first group has simple complexity level, two workers, and high skill level. The second group has moderate complexity level, two workers, and high skill level. The third group has high complexity level, two workers, and high skill level. The forth group has simple complexity level, four workers, and high skill level. The fifth group has moderate complexity level, two workers, and low skill level. These five groups were considered to help in providing the experimental control over the three variables. For each combination, seven experiments were performed, leading to a total of 35 experiments. All the experiments were performed and filmed using a video camera. The purpose of filming the experiments was to improve the accuracy of taking the observations by eliminating observer fatigue, and by improving the ability of the observer in identifying the work activity at a precise instant.

The construction craft selected for this study was masonry. Unlike other crafts, there is a possibility of the reuses of the materials in masonry. The reuses of concrete blocks used in this study did save much time and money. In addition, masonry is one of

the crafts discussed by Thomas (Thomas, 1991).

This study was presented to different companies to find a company willing to participate. However, only one company, MUAN, was interested in participating in this study. The main work specialty of this company is telecommunication. However, a number of qualified masons were available in this company. The researcher had a previous experience with this company which made communication very easy between both parties.

3.4.1 Categories, And Observations

For each experiment, the observations were gathered randomly based on the categories of effective work, essential contributory work, and ineffective work categories. The effective work category was defined as the category that contains any of the activities necessary for building the wall as designed and within the acceptable level of quality, and the essential contributory work category was defined as the category that contains all the activities supporting those of effective work category. In addition, the ineffective work category was defined as the category that contains all the activities that are not related to those of the effective work category. The definitions of the three categories were used to classify all the activities observed. All the activities that were found to match the definition of one category were grouped together to represent the observations of that category.

As most of the other studies in this field, this study used a confidence level of

95%, category proportion of 50%, and a limit of error of 5%. However the number of observations collected was 400 per experiment. This adds up to a total of 14,000 observations for the whole study.

3.4.2 Preparations For The Experiments

3.4.2.1 Workers

At the beginning of the study, all the workers were interviewed to explain to them the purpose of the study, to reduce their fear from the video camera, and to assure them that they will not be evaluated by this study. This was to make sure that they will do the job as normal as possible. In addition, five minute meetings were made at the beginning of some of the experiments to remind the workers of the level of quality that must be maintained. However, the communication with the worker was not easy because some of the workers do not speak English. However, the information was conveyed to them through an interpreter.

A total of six workers were allowed to participate in this study. Four of them were of a high skill level, and the other two were of a low skill level. Five of the workers were Indians and one was a Nepali. The selection of the workers was based on the evaluation of their Foreman.

3.4.2.2 Location

All the experiments were performed at a workshop in Alnabyah. This location that is shown in Figure 3.4, is one of the facilities of MUAN at which the proper area needed for the study was found. This location was ideal because the tools' storage, and workers' residence, were nearby. In addition it had a large area, the area of the workshop is 300 meter square (15m by 20 m).

The work location, mortar location, block location, and camera location are shown in Figure 3.5. At the entrance of the workshop an area of 20 meter square (5 m by 4 m) was designated as the work location. This area is represented by letter E. Letter F represents the location of the mortar. The blocks are located at two places that are marked by the letters B and C. Letter D shows the location of the mock that was built to show the required quality. The video camera location was about 12 meters away from the center of the work area. This location is marked by the letter A.

The arrangement shown in Figure 3.5 was mainly due to the filming requirements, accessibility of materials, and the rules of the company. There were some filming requirements that were important to be fulfilled, such as to make sure that there was enough light at the work locations, and all the locations of work, materials, and mortar were contained. Also, all the materials needed for the work should be handy and near the work location. In addition, there were some rules by the company such as not to mix any cement inside the workshop. So, all the previously mentioned reasons contributed to the arrangement shown in Figure. 3.5.

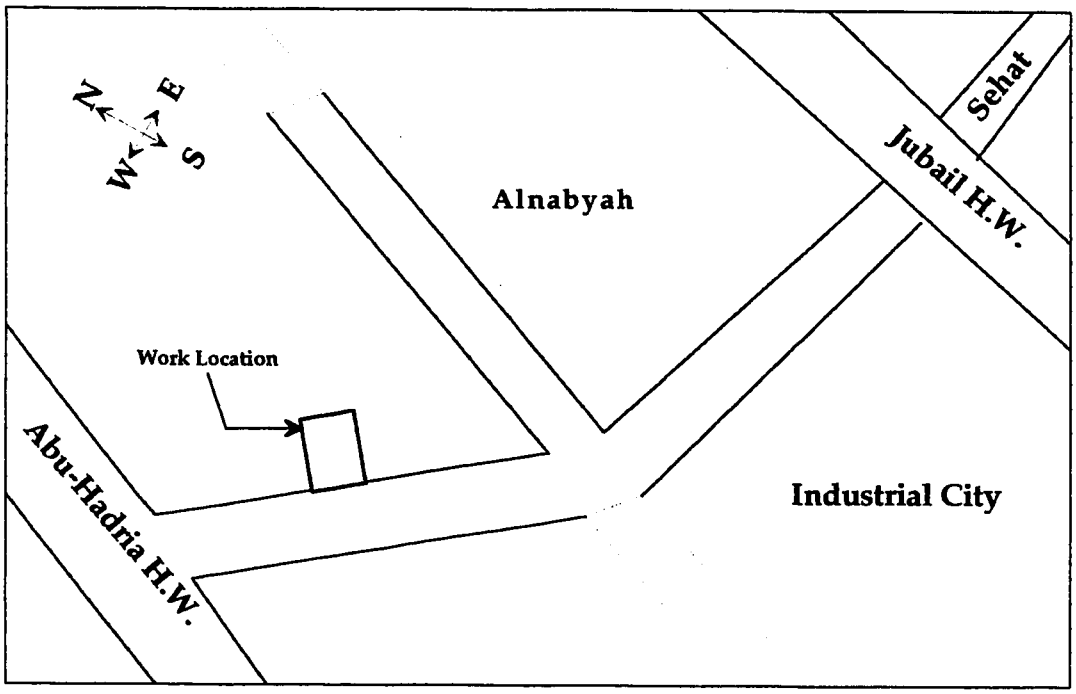

Figure 3.4 - Work Location

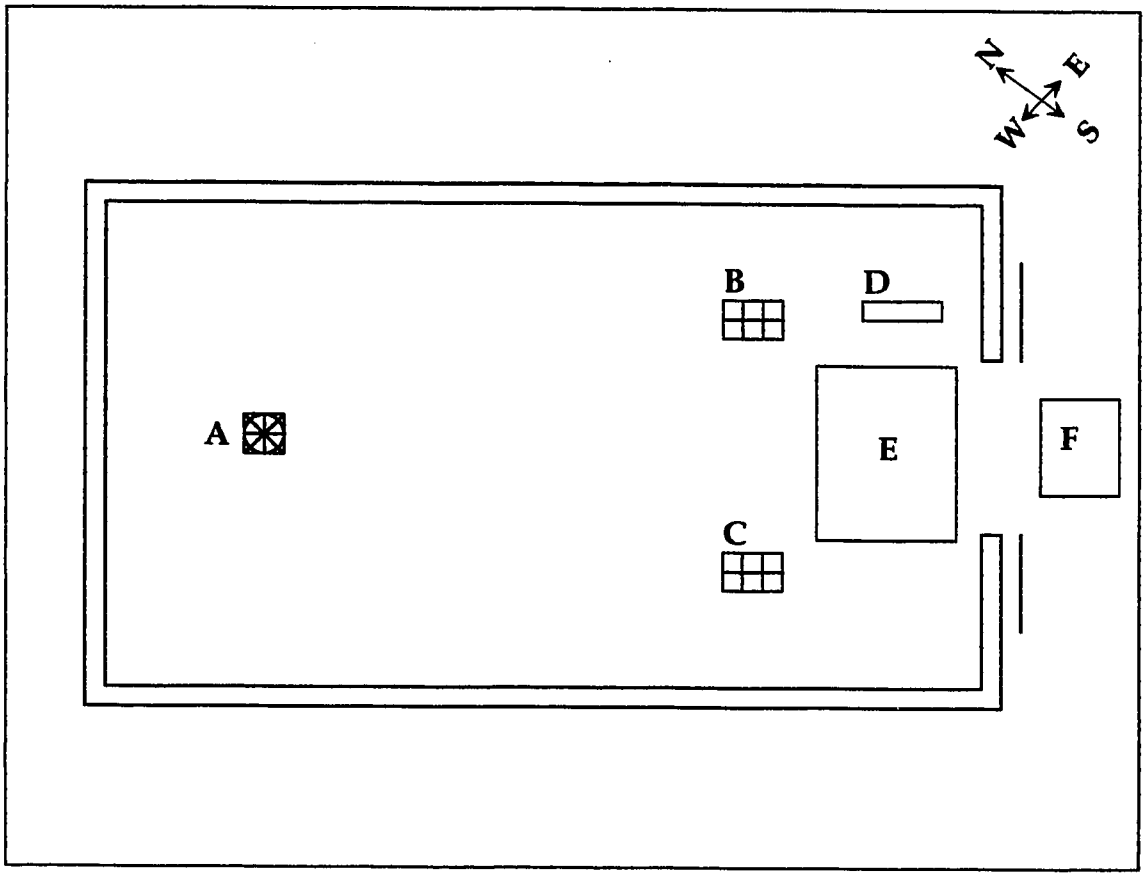

Figure 3.5 - Layout Of Work Location

3.4.2.3 Tools

The tools used in the experiment were those of a regular mason. However, more emphasis will be on those used frequently by the activities observed. The tools used were the robe, the plumb line, and the Aluminum bar. At the start of each experiment, the workers tie a string between two concrete blocks. This help in aligning the first course of blocks. Then, the string was taken out to move freely. The plumb line was used for vertical alignment. The Aluminum bar was 3 meter long and it was used to make sure that surface of the wall was aligned.

3.4.2.4 Materials

The materials used in this study were concrete blocks, sand, water, and cement. For all the experiments, a total of 200 concrete blocks and 6 cement bags, each with a weight of 50 KG, were used. The small number of blocks used was due to the repetitive reuse of these blocks. After each experiment, the wall was dismantled, the blocks were cleaned from mortar and left aside to dry, and the mortar was thrown away.

3.5 Data Collection

3.5.1 Filming Of The Experiments

The filming of the study took eight days. In these days 35 experiments were

performed and filmed. Table 3.1 shows the schedule of the filming of the 35 experiments and some other related information. This information is about the duration, complexity level, crew size, and skill level of each experiment.

For the purpose of filming the experiments, a set of filming equipment was provided by the department of CEM. This set consists of a JVC video camera (Video Movie, GF-500), batteries, stand, and extension wires. Also, a high quality Samsung Video Cassette Recorder (VZ-S95) was used for viewing the tapes of the experiments. This video had its own timer that shows the time in hours, minutes, and seconds. This timer was tested before it was used.

The procedure of filming followed the following steps. First, the Video Camera set was attached and the extension cables were connected to provide power for the Video Camera. After that, the mortar used for the experiments was prepared. Then the tape that will be used was marked with the number of experiment and rewound. While the tape was being rewound, the workers were interviewed to check their readiness for work and the materials and tools were checked out. Then, the workers were permitted to work and the recording starts. Then, the necessary information like the starting time of the experiment was written down. From time to time the video camera was checked to make sure that every thing was working normally. Once the wall was finished, the recording was stopped and the information related to time, complexity level, crew size, and skill level were written on the tape for each experiment.

Exp	Day	Date	Starting time	Duration	Complexity Level	Crew Size	Skill Level
01	Sat	11-19-94	08:32 A m	1.600 hr	I	02	H
02	Sat	11-19-94	10:38 A m	1.142 hr	I	02	H
03	Sat	11-19-94	01:08 P m	1.103 hr	I	02	H
04	Sat	11-19-94	02:37 P m	0.923 hr	I	02	H
05	Sun	11-20-94	07:16 A m	1.105 hr	I	02	H
06	Sun	11-20-94	08:46 A m	0.973 hr	I	02	H
07	Sun	11-20-94	10:18 A m	0.885 hr	I	02	H
08	Sun	11-20-94	12:37 P m	1.404 hr	II	02	H
09	Sun	11-20-94	02:34 P m	1.088 hr	II	02	H
10	Mon	11-21-94	07:32 A m	1.295 hr	II	02	H
11	Mon	11-21-94	09:10 A m	1.332 hr	II	02	H
12	Mon	11-21-94	10:59 A m	1.279 hr	II	02	H
13	Mon	11-21-94	12:50 P m	1.367 hr	II	02	H
14	Tue	11-22-94	07:19 A m	1.291 hr	II	02	H
15	Tue	11-22-94	09:05 A m	1.588 hr	III	02	H
16	Tue	11-22-94	11:33 A m	1.471 hr	III	02	H
17	Tue	11-22-94	01:20 P m	1.454 hr	III	02	H
18	Wed	11-23-94	07:27 A m	1.441 hr	III	02	H
19	Wed	11-23-94	09:25 A m	1.504 hr	III	02	H
20	Wed	11-23-94	12:04 P m	1.540 hr	III	02	H
21	Wed	11-23-94	02:11 P m	1.334 hr	III	02	H
22	Thd	11-24-94	07:27 A m	1.383 hr	I	04	H
23	Thd	11-24-94	09:07 A m	0.883 hr	I	04	H
24	Thd	11-24-94	10:19 A m	0.914 hr	I	04	H
25	Thd	11-24-94	11:20 A m	0.817 hr	I	04	H
26	Thd	11-24-94	12:46 P m	0.923 hr	I	04	H
27	Thd	11-24-94	01:54 P m	0.645 hr	I	04	H
28	Thd	11-24-94	02:46 P m	0.529 hr	I	04	H
29	Sat	11-26-94	07:30 A m	1.724 hr	II	02	L
30	Sat	11-26-94	09:50 A m	1.568 hr	II	02	L
31	Sat	11-26-94	12:20 P m	1.324 hr	II	02	L
32	Sat	11-26-94	02:13 P m	1.336 hr	II	02	L
33	Sun	11-27-94	07:17 A m	1.405 hr	II	02	L
34	Sun	11-27-94	09:07 A m	1.317 hr	II	02	L
35	Sun	11-27-94	10:49 A m	1.282 hr	II	02	L

Table 3.1 - Experiments And Filming Time

3.5.2 Selecting Time Instants For Observations

In work sampling the observations should be taken randomly. Since all the observations were going to be taken from the video tapes, the duration of each experiment was needed to prepare for the random timings. For this study, 400 random instants are required for each experiment run, or a total of 14,000 instants.

For the generation of the random instants both tables of random numbers and Quattro Pro software were used. First, the table of random numbers was used to generate those timings. In this study, the table of random numbers provided by Ostle and Mensing (1975) was used (The table of random numbers is shown in Appendix A). However, it was time consuming process and its use was discontinued. So, Quattro Pro software was used to generate those instants of time and arrange them, which helped in saving much time.

In both methods, the duration of each experiment run governed the selection of random numbers. For example, the duration of experiment #1, was one hour and 36 minutes. So, the selection of hours was either zero or one, the selection of minutes was from zero to 59 minutes for zero hour, and from zero to 35 for one hour, and the selection of seconds was from zero to 60 seconds. Using the table of random numbers, the selection of an hour depends on the number selected. An even number meant zero hour, and an odd number meant one hour. However, for the minutes, each number within the range of the minutes was selected. Likewise, for the seconds all the numbers within their range were selected. The same procedure was followed using the Quattro Pro software. However, the

random instants of time were generated at once using this approach. Samples of the instants used in this study for the 35 experiments are presented in Appendix B.

3.5.3 Viewing Of The Experiments

The viewing of the experiments started by selecting the experiment intended to be viewed. This means that the tape of this experiment and the random timing for it were selected. Then, the VCR was operated and checked. The checking of the VCR was to make sure that the wires were connected, the timer was working, and the viewing was clean. Then, the video tape was played to pick the starting point of the experiment. At the starting point the timer was started. Then, the observations were taken based on the random instants previously prepared. At each instant, the video tape was paused to take the observations of all the workers. The action or the activity of each worker was identified and was given a number. When the activities were observed, the number representing these activities were listed on the observation sheet. The activities observed for some samples of the experiments are shown in Appendix B.

At the beginning of the viewing, there were some difficulties in understanding the activity and the action of the workers. After viewing 10 tapes, it became easy to identify and understand the actions of the workers. The first video tape took twelve hours to be viewed. However, the last one took only two and half hours to be viewed.

The filming of the 35 experiments used 35 video tapes. The recording time of all the 35 tapes is 41 hours and 47 minutes.

3.6 Data Analysis

3.6.1 Productivity And Categories Percentages

The variables needed for the calculation of productivity were the number of blocks, the number of workers, and the duration of each experiment. These variables were inputted to a Quattro Pro spreadsheet and the following equation was used,

$$productivity = \frac{No.\ of\ Bloocks}{No.of\ workers * Duration} \qquad (6)$$

For the counting of the observations of each activity a small program was written. In this program all the observations were inputted to add the total observations of each activity. Then, the observations of the activities of each experiment were inputted into the spreadsheet. Then, the activities satisfying the definition of the same category were added together to give the percentage of the category for each experiment. The results of productivity and categories' percentages are presented in Chapter 4.

3.6.2 Relationship Between Productivity And Work Sampling Categories

The relationships between productivity and effective work category, productivity and ineffective work category, and effective work category and ineffective work category were investigated using the Pearson coefficient of correlation.

The coefficient of correlation is a unitless measure of the linear relationship

between the variables in a set of data. The value of the coefficient of correlation ranges from (-1) to (+1). A value of (+1) represents a direct relationship, while a value of (-1) represent an inverse relationship. On the other hand, a value of (0) represents no relationship.

The coefficient of correlation of each relationship was computed, and the results were used to test the hypotheses stated in section 3.2.

3.6.3 The Effect Of Influencing Variables On The Relationships

The effect of the influencing variables on the three relationships was investigated using two approaches. Both experimental and statistical controls were used to study the effect of complexity level, crew size, and skill level on these relationships.

3.6.3.1 Experimental Control

The design of this study helped in providing the experimental control over complexity level, crew size, and skill level. The five groups of data mentioned in the study design section were used to analyze the effect of each variable on the relationship between productivity and effective work category, productivity and ineffective work category, and effective work category and ineffective work category.

The effect of complexity level on the three relationships was studied by comparing the coefficients of correlation of three sets of experiments: experiments 1 to 7, experiments 8 to 14, and experiments 15 to 21. In these three sets, crew size and skill level are constant but the complexity level varies. Also, the effect of crew size on the relationships was studied by comparing the coefficients of correlation of two sets of experiments: experiments 1 to 7, and experiments 22 to 28. In these two sets, skill level and complexity level are constant but the crew size varies. In addition, The effect of skill level on the relationships was studied by comparing the coefficients of correlation of two sets of experiments: experiments 8 to 14, and experiments 29 to 35. In these two sets, the complexity level and the crew size are constant but the skill level varies. These results are presented and discussed in Chapter 4.

3.6.3.2 Statistical Control

Statistical control is an additional technique used in this study to investigate the effect of complexity level, crew size, and skill level on the relationship between work sampling and productivity. Statistical control of these variables was made using partial correlation. The first order partial correlation used in this study has the following equation (Cohen, 1975),

$$r_{xy.z} = \frac{(r_{xy} - r_{xz}r_{yz})}{\sqrt{(1-r_{xz}^2)(1-r_{yz}^2)}} \qquad (7)$$

In this equation, $r_{xy.z}$ is the coefficient of correlation between X and Y while the effect of the variable Z is partialled out. In other words, the coefficient of correlation between X and Y is calculated while controlling the effect of Z on this relationship between X and Y. Then, the coefficient of correlation when one of the variables was controlled will be compared to that before controlling the same variable to find the difference between them. The difference was tested using Fisher's z transformation. Then, the coefficients of correlation before (r_b) and after (r_a) the control of the variables were used in equations (8) and (9), (Cohen, 1975), to give z'_b , and z'_a , respectively.

$$z'_b = \frac{1}{2}[\ln(1 + r_b) - \ln(1 - r_b)] \qquad (8)$$

$$z'_a = \frac{1}{2}[\ln(1 + r_a) - \ln(1 - r_a)] \qquad (9)$$

Then, equation (10) was used to compare between z'_b , and z'_a (Cohen, 1975). The results of this equation gave the deviation on the normal curve (z). Then, the probability of the similarity between the two coefficients of correlation was found based on the deviation on the normal curve and using the table presented in Appendix C.

$$z = \frac{z'_b - z'_a}{\sqrt{\frac{1}{n-3}}} \qquad (10)$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Work Sampling And Productivity

In this part of the study the data required for the calculation of productivity and finding the percentages of the work sampling categories will be presented. Also, some discussion will be made based on those results.

4.1.1 Productivity

In this study, the definition used for productivity is the number of blocks used for building the wall per man-hours used to finish the same wall. The term man-hours was obtained by multiplying the number of workers of the crew by the duration of the experiment. There were three variables that were used to calculate productivity. These variables were the crew size or number of workers for each crew, the number of blocks used to build each wall, and the time taken to build each wall.

The control over the number of workers participating in this study was limited by their availability and their work schedule. Two different crew sizes were used for this study. The first contained two workers and the second contained four workers. There

were 28 experiments made using a crew size of two (experiments 1 to 21, and 29 to 35), and 7 experiments made using a crew size of four (experiments 22 to 28).

The number of blocks used for each experiment depended on the complexity of the wall built for the same experiment. There were three different complexity levels used in this study, which are simple (type -I), moderate (type -II), and complex (type -III). The number of blocks used for these complexity levels were 56, 63, and 70 blocks respectively.

The duration for each experiment depended on the combined effect of the three variables. As shown in table 4.1, the duration of the experiments ranged from 0.529 hours (Exp. 28), to 1.724 hours (Exp. 29).

The calculation for productivity was made using Equation (6). The data of crew size, duration, and number of blocks used for the calculations of productivity and their results are presented in Table 4.1. The results show that productivity ranges from 10.12 blocks per man-hour (Exp. 22) to 31.648 blocks per man-hour (Exp. 7) with an average of 22.85 blocks per man-hour, and a standard deviation of 4.48 blocks per man-hour.

4.1.2 Work Sampling

In this study all the experiments were filmed by a video camera. All the video tapes were viewed a number of times (two or three) to take the observations of the activities. Then, the activities were gathered in three categories. These categories are effective work, essential contributory work, and ineffective work category.

Exp	Crew Size	Duration (Hour)	No. of Blocks	Productivity (Blocks/Man-Hour)
01	2	1.600	56	17.500
02	2	1.142	56	24.526
03	2	1.103	56	25.378
04	2	0.923	56	30.334
05	2	1.105	56	25.346
06	2	0.973	56	28.767
07	2	0.885	56	31.648
08	2	1.404	63	22.438
09	2	1.088	63	28.958
10	2	1.295	63	24.319
11	2	1.332	63	23.645
12	2	1.279	63	24.620
13	2	1.367	63	23.049
14	2	1.291	63	24.403
15	2	1.588	70	22.036
16	2	1.471	70	23.792
17	2	1.454	70	24.069
18	2	1.441	70	24.282
19	2	1.504	70	23.269
20	2	1.540	70	22.727
21	2	1.334	70	26.234
22	4	1.383	56	10.120
23	4	0.883	56	15.849
24	4	0.914	56	15.319
25	4	0.817	56	17.143
26	4	0.923	56	15.172
27	4	0.645	56	21.696
28	4	0.529	56	26.457
29	2	1.724	63	18.267
30	2	1.568	63	20.096
31	2	1.324	63	23.784
32	2	1.336	63	23.581
33	2	1.405	63	22.420
34	2	1.317	63	23.919
35	2	1.282	63	24.572

Table 4.1 - Productivity Results Of Each Experiment

4.1.2.1 Identification Of Activities

By viewing all the video tapes, a total of 27 different activities were observed. Each activity was given a definition and a number.. The number given to each activity shows the sequence of observing that activity for all the experiments. The observed activities are:

1- Move concrete block from work location and place it on exact location on the wall.

2- Move concrete blocks from their location to work location.

3- Place a bed of mortar on the required spot.

4- Lift concrete blocks from the ground to transport them to work location.

5- Doing nothing (Idle).

6- Place concrete blocks at work location.

7- Level the course of concrete blocks or balance the concrete block (either by using the Aluminum bar or the plumb line).

8- Mix mortar and place in a bucket.

9- Lift mortar bucket (either to take it to work location or to mortar location).

10- Go to concrete blocks location.

11- Take the plumb line to work locations.

12- Brake and cut the concrete block to the required sizes.

13- Take the Aluminum bar back to its original location.

14- No contact.

15- Fill and finish the wall joints using mortar.

16- Take the string away (this string is used to help lining the course of blocks).

17- Go to mortar location.

18- Take the Aluminum bar to work locations.

19- Delay.

20- Place the mortar bucket at work location.

21- Drink water.

22- Clean the Aluminum bar.

23- Wear gloves.

24- Take concrete block back from its location on the wall.

25- Take the plum line a way.

26- Clean the surface of the concrete block.

27- Clean the ground from mortar.

For each experiment a total of 400 observations were taken. So, for all the experiments a total of 14000 observations were taken. Table 4.2 shows the frequencies of activities broken down by experiment and type. In this table, each column represents an activity, and each row represents an experiment. So, each cell in the table represents the number of observations of an activity for a particular experiment.

For all the experiments, the most observed activity was filling and finishing the wall joints using mortar (Activity 15). This activity was observed 3007 times. In contrast, the lowest observed activities are cleaning the Aluminum bar and cleaning the ground from mortar (Activities 22 and 27). Those activities were observed 5 times each only.

EXP	Activities																											Total
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
01	17	05	59	16	91	02	94	13	02	10	02	05	01	16	67	00	00	00	00	00	00	00	00	00	00	00	00	400
02	05	01	41	05	41	04	60	02	00	03	00	02	01	22	202	02	06	03	00	00	00	00	00	00	00	00	00	400
03	21	04	49	03	49	03	48	19	00	09	00	00	00	32	161	00	00	02	00	00	00	00	00	00	00	00	00	400
04	30	07	77	11	63	07	78	43	00	09	02	03	02	19	38	02	00	09	00	00	00	00	00	00	00	00	00	400
05	10	09	48	03	30	01	74	24	00	08	00	01	02	05	182	01	00	02	00	00	00	00	00	00	00	00	00	400
06	20	09	89	11	74	06	76	48	01	13	04	09	02	05	24	01	06	02	00	00	00	00	00	00	00	00	00	400
07	26	08	93	11	25	07	75	44	00	16	02	14	00	06	61	01	06	03	02	00	00	00	00	00	00	00	00	400
08	25	07	66	05	78	02	81	24	00	11	02	12	00	08	74	00	01	01	03	00	00	00	00	00	00	00	00	400
09	15	06	41	07	23	07	94	28	00	07	02	00	06	22	127	00	05	03	00	00	02	05	00	00	00	00	00	400
10	41	06	53	01	23	04	79	29	02	09	06	00	01	08	119	03	06	01	00	02	00	00	02	00	01	04	00	400
11	17	07	71	07	50	01	97	21	02	05	03	00	02	12	93	02	00	02	00	00	03	00	05	00	00	00	00	400
12	24	08	75	03	17	04	99	19	01	14	06	00	01	25	96	00	05	01	00	02	00	00	00	00	00	00	00	400
13	16	05	94	07	67	02	101	17	03	03	01	00	00	05	69	01	07	02	00	00	00	00	00	00	00	00	00	400
14	26	01	95	09	53	02	103	15	01	06	01	01	03	30	54	00	00	00	00	00	00	00	00	00	00	00	00	400
15	48	06	57	04	27	06	85	23	04	08	05	00	01	12	94	02	04	00	00	00	00	00	02	03	05	02	02	400
16	26	09	71	07	50	04	91	20	08	08	03	00	05	12	79	01	01	03	01	01	00	00	00	00	00	00	00	400
17	43	04	45	05	33	02	86	20	03	06	11	00	03	20	109	00	02	03	00	00	00	00	00	00	02	03	00	400
18	50	06	55	11	44	04	68	20	04	12	04	00	01	17	87	00	01	02	00	03	00	00	01	00	04	06	00	400
19	48	06	61	10	66	06	77	26	03	09	06	00	01	03	69	01	03	02	00	01	00	00	01	00	01	00	00	400
20	35	10	59	11	39	08	93	26	02	08	10	00	03	06	76	00	06	03	03	00	01	00	00	00	01	00	00	400
21	39	04	62	03	68	03	91	21	05	14	04	00	02	04	59	03	04	01	03	05	00	00	02	00	01	01	01	400
22	09	00	41	03	160	05	55	18	06	04	00	00	01	20	76	00	00	02	00	00	00	00	00	00	00	00	00	400
23	09	05	45	12	109	02	57	25	04	08	00	00	02	36	79	01	00	06	00	00	00	00	00	00	00	00	00	400
24	15	09	41	08	145	02	64	31	01	07	00	00	03	09	62	02	00	01	00	00	00	00	00	00	00	00	00	400
25	21	03	39	06	155	04	43	18	01	08	00	00	01	29	71	00	00	01	00	00	00	00	00	00	00	00	00	400
26	20	06	41	08	169	06	40	22	01	06	00	00	02	36	39	00	00	04	00	00	00	00	00	00	00	00	00	400
27	26	07	38	04	145	06	51	15	02	12	00	00	00	15	73	02	00	04	00	00	00	00	00	00	00	00	00	400
28	21	07	46	05	91	04	90	26	06	12	01	00	02	31	52	03	00	03	00	00	00	00	00	00	00	00	00	400
29	31	13	61	11	43	01	103	12	00	12	02	00	01	17	89	00	01	01	00	00	00	00	00	01	00	01	00	400
30	37	08	68	04	64	05	86	21	00	11	00	00	01	11	70	00	02	03	00	00	01	00	00	00	00	06	02	400
31	26	06	46	16	70	05	71	12	02	04	02	00	00	67	65	00	02	02	00	00	00	00	00	01	02	01	00	400
32	31	07	49	08	72	06	89	12	01	04	01	00	03	43	69	00	01	03	00	00	00	00	00	01	00	00	00	400
33	36	13	50	08	43	04	81	08	01	19	00	00	01	21	110	01	00	00	01	02	00	00	01	00	00	00	00	400
34	22	06	51	09	39	06	106	09	06	24	01	00	01	23	90	00	02	03	01	00	00	00	00	01	00	00	00	400
35	30	10	58	13	38	01	96	06	02	05	00	00	03	08	122	02	02	02	00	01	00	00	01	00	00	00	00	400
Total	916	228	2035	265	2354	142	2782	737	74	324	81	47	58	655	3007	31	73	80	14	17	07	05	15	07	17	24	05	14,000

Table 4.2 - Frequencies Of Activities Observed For Each Experiment

Table 4.3 shows the percentage of occurrence, mean, high, low, standard deviation, of each experiment.

4.1.2.2 Categories

After spending much time with the masons the researcher became familiar with the intricacies of the tasks performed. This helped the researcher in the classification of the activities based on the definitions presented in the Methodology Chapter.

The rule used in the classification of activities is that all activities necessary for the completion of work and needed to maintain the quality level were considered as effective work activities. These activities are the basic activities that will never be affected when the layout of work location is changed nor when different crews of different size and skill level are used. Furthermore, any activity that has nothing to do with the work or unnecessary to be made would be considered as an ineffective work category. The No Contact activity (Activity 14) was added to this category because the availability of material and tools on the work location. So, the absence of the worker has no relation with the work or they are doing unnecessary work. Finally, all the activities that do not belong to any of the above two categories would be considered in the essential contributory work category. The categories and classification of the activities are shown below.

ACTIVITY	PERCENT	Frequency				
		TOTAL	MEAN	MAX.	MIN.	S.D.
01	06.54	0916	26.17	050	05	11.58
02	01.63	0228	06.51	013	00	02.89
03	14.54	2035	58.14	095	38	16.52
04	01.89	0265	07.57	016	01	03.79
05	16.81	2354	67.26	169	17	42.09
06	01.01	0142	04.06	008	01	02.03
07	19.87	2782	79.49	106	40	18.08
08	05.26	0737	21.06	048	02	09.99
09	00.53	0074	02.11	008	00	02.11
10	02.31	0324	0926	024	03	04.55
11	00.58	0081	02.31	011	00	02.80
12	00.34	0047	01..34	014	00	03.42
13	00.41	0058	01.66	006	00	01.37
14	04.68	0655	18.71	067	03	13.48
15	21.48	3007	85.91	202	24	37.94
16	00.22	0031	00.89	003	00	01.02
17	00.52	0073	02.09	007	00	02.38
18	00.57	0080	02.29	009	00	01.74
19	00.10	0014	00.40	003	00	00.91
20	00.12	0017	00.49	005	00	01.10
21	00.05	0007	00.20	003	00	00.63
22	00.04	0005	00.14	005	00	00.85
23	00.11	0015	00.43	005	00	01.01
24	00.05	0007	00.20	003	00	00.58
25	00.12	0017	00.49	005	00	01.15
26	00.17	0024	00.69	006	00	01.61
27	00.04	0005	00.14	002	00	00.49

Table 4.3 - Simple Statistics For All The Activities Observed

Effective Work Category

Based on the above, only four activities fall in this category and these activities are,

1- Move concrete block from work location and place it on exact location on the wall.

3- Place a bed of mortar on the required spot.

7- Level the course of concrete blocks or balance the concrete block (either by using the Aluminum bar or the plumb line).

15- Fill and finish the block joints.

Although the number of activities in this category is low, their frequencies are high. For all the experiments, this category contains a total of 8740 observations. Table 4.4 shows the percentages of this category for each experiment. The percentages of this category range from 35 % (Experiment 26) to 78.5% (Experiment 5), with an average of 62.43%, and a standard deviation of 10.88%.

Essential Contributory Work Category

Based on the definition of essential contributory work given in the Methodology Chapter, a total of 16 activities fall in this category and they are,

2- Move concrete blocks from their location to work location.

4- Lift concrete blocks from the ground to transport them to work location.

6- Place concrete blocks at work location.

8- Mix mortar and place in bucket.

9- Lift mortar bucket (either to take it to work location or to mortar location).

Exp.	Percentages		
	Effective Work	Essential Contributory Work	Ineffective Work
01	59.25	14.00	26.75
02	77.00	07.25	15.75
03	69.75	10.00	20.25
04	55.75	23.75	20.50
05	78.50	12.75	08.75
06	52.25	28.00	19.75
07	63.75	28.00	08.25
08	61.50	16.25	22.25
09	69.25	19.00	11.75
10	73.00	18.75	08.25
11	69.50	13.00	17.50
12	73.50	16.00	10.50
13	70.00	12.00	18.00
14	69.50	09.75	20.75
15	71.00	17.50	11.50
16	66.75	17.50	15.75
17	70.75	16.00	13.25
18	65.00	19.50	15.50
19	63.75	18.75	17.50
20	65.75	22.00	12.25
21	62.75	17.75	19.50
22	45.25	09.75	45.00
23	47.50	16.25	36.25
24	45.50	16.00	38.50
25	43.50	40.50	16.00
26	35.00	13.75	51.25
27	47.00	13.00	40.00
28	52.25	17.25	30.50
29	71.00	13.75	15.25
30	65.25	15.25	19.50
31	52.00	13.50	34.50
32	59.50	11.50	29.00
33	69.25	14.25	16.50
34	67.25	16.75	16.00
35	76.50	11.75	11.75
Average	62.43	15.74	21.85

Table 4.4 - Percentages Of Effective Work, Essential Contributory Work,

And Ineffective Work

10- Go to concrete blocks location.

11- Take the plumb line to work locations.

12- Brake and cut the concrete block to the required sizes.

13- Take the Aluminum bar back to its original location.

16- Take the string away (this string is used to help lining the course of blocks).

17- Go to mortar location.

18- Take the Aluminum bar to work locations.

20- Place the mortar bucket at work location.

22- Clean the Aluminum bar.

25- Take the plumb line a way.

26- Clean the surface of the concrete block.

The number of activities related to this category is very high, however, their frequency is only 2203 representing 15.74% of the total observations. The individual percentage of this category of each experiment is presented in table 4.4. The percentages of this category range from 7.25% in experiment 2 to 40.5% in experiment 25, with a standard deviation of 4.71%.

Ineffective Work Category

Based on the definition stated in the Methodology Chapter, seven activities fall in this category and they are,

5- Doing nothing (Idle).

14- No contact.

19- Delay.

21- Drink water.

23- Wear gloves.

24- Take concrete block back from its location on the wall (rework).

27- Clean the ground from mortar.

For all the experiments, this category has a frequency of 3057, representing 21.85% of the total observations. Also, Table 4.4 is used to present the percentage of this category for each experiment. The percentages range from 8.25% as in experiments # 7 and # 10 to 51.25% as in experiment 26, with an average of 21.85%, and a standard deviation of 11.57%.

4.2 Relationship Between Productivity And Effective Work Category

The relationship between productivity and effective work category is shown in Figure 4.1. In this figure, 35 data points were used to describe this relationship. Although the data points did not show a strong relationship between productivity and effective work category, they did indicate that the two variables are directly related.

The strength of the relationship was found by computing the Pearson coefficient of correlation for all the data points. The coefficient of correlation was found to be 0.498 with a significance level less than 0.005. The result indicates a moderate positive relationship between productivity and effective work category.

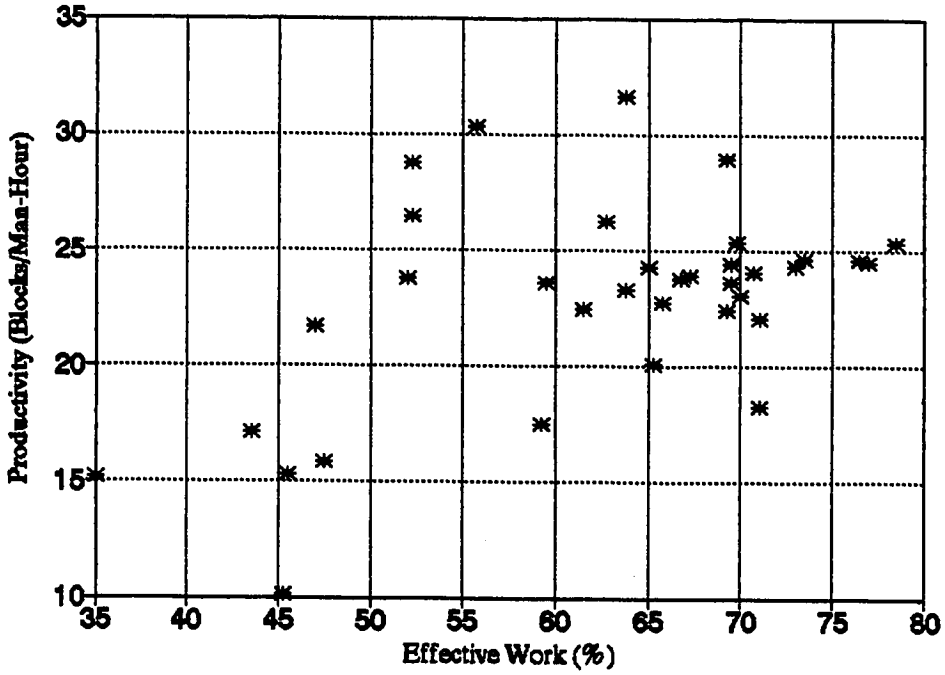

Figure 4.1 - Relationship Between Productivity And Effective Work

Category For All Data Points

Furthermore, it is important to know if the same relationship was going to stand the variation in any of the influencing variables. So, the effects of complexity level, crew size, and skill level on the relationship were investigated.

4.2.1 The Effect Of Complexity Level On The Relationship

The effect of complexity level on the relationship between productivity and effective work was investigated in two ways. Both experimental and statistical controls of complexity level were made to find its' effect on the relationship. The result of each approach is presented in the following two sections.

4.2.1.1 Experimental Control

Three groups of data having the same skill level and crew size but different complexity levels, were used to report the different complexity levels used in this study. These groups of data are of experiments 1 to 7, experiments 8 to 14, and experiments 15 to 21. Figure 4.2 shows the relationship between productivity and effective work category using these three groups of data. In this figure, none of these data groups shows a clear relationship between productivity and effective work category.

The coefficient of correlation of these groups of data was computed. $r_{1\text{-}7}$ was found to be -0.218 ($p = 0.64$, N.S.) , $r_{8\text{-}14}$ was found to be 0.290 ($p = 0.53$, N.S..). Also, $r_{15\text{-}21}$ was found to be -0.553 ($p = 0.2$, N.S.).

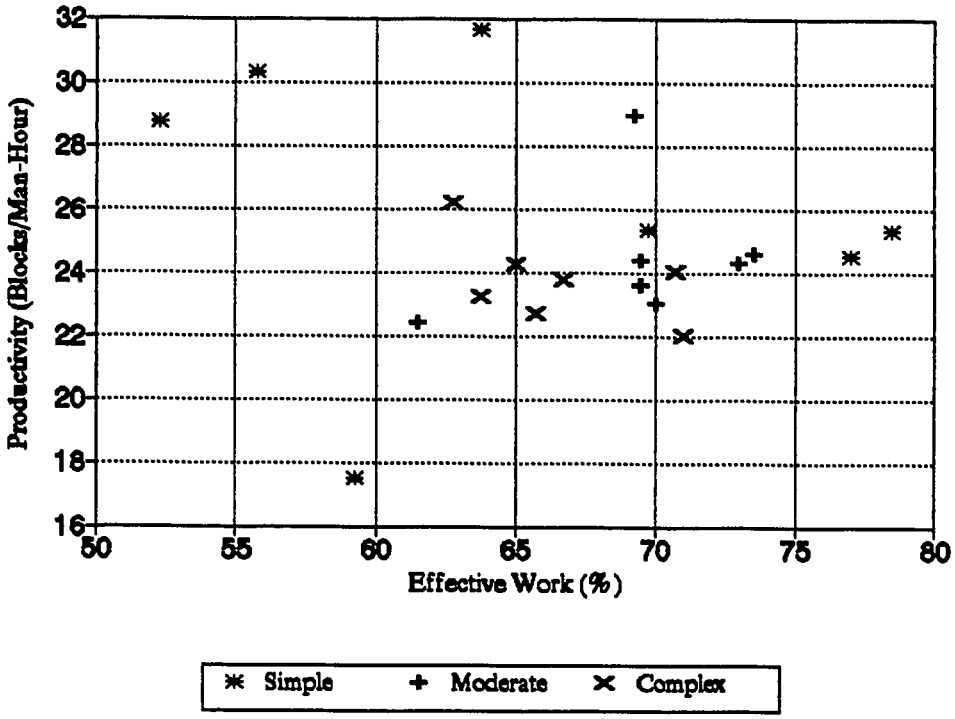

Figure 4.2 - Relationship Between Productivity And Effective Work Category For Simple, Moderate, And Complex Levels Of Complexity

The non significant correlation (N.S.), though primarily caused by the limited sample size in each category, and restriction of range, prevents any further analysis of the magnitude of the obtained correlation.

4.2.1.2 Statistical Control

When controlling the effect of complexity level statistically, the coefficient of correlation (partial correlation) between productivity and effective work category was found to be 0.475 with a significance level less than 0.005. This indicates a moderate positive relationship between productivity and effective work category.

The effect of complexity level was investigated by comparing the coefficient of correlation before and after the control of complexity level. The comparison between the two coefficients of correlation that are 0.498 and 0.475, using Fisher's test, indicated that there is no difference between them.

This suggests that complexity level has no effect over the relationship between productivity and effective work. However, an alternative interpretation could be that there was no real variation in the complexity levels to affect the relationship between productivity and effective work category.

4.2.2 The Effect Of Crew Size On The Relationship

Both experimental and statistical controls were used in investigating the effect of

crew size on the relationship between productivity and effective work category. The results of using these approaches are presented below.

4.2.2.1 Experimental Control

The experimental investigation of the effect of crew size on the relationship between productivity and effective work was made using two groups of data having the same complexity and skill levels but different crew sizes. These were data points of experiments 1 to 7, and experiments 22 to 28. Figure 4.3 shows the relationship between productivity and effective work using these two groups of data. This figure shows that there is a direct relationship using the data of the four workers. However, the relationship is not clear for the data group with two workers.

In the computation of coefficient of correlation for the two groups of data, $r_{1\text{-}7}$ was found to be -0.218 (p = 0.64, N.S.), and $r_{22\text{-}28}$ was found to be 0.546 (p = 0.21, N.S.) . The non significant correlation, though primarily caused by the limited sample size, preclude any further analysis of the results.

4.2.2.2 Statistical Control

The statistical control of crew size gave a partial correlation of 0.0021 between productivity and effective work. The high significance level of 0.991 and the low coefficient of correlation showed that there is no relationship between productivity and

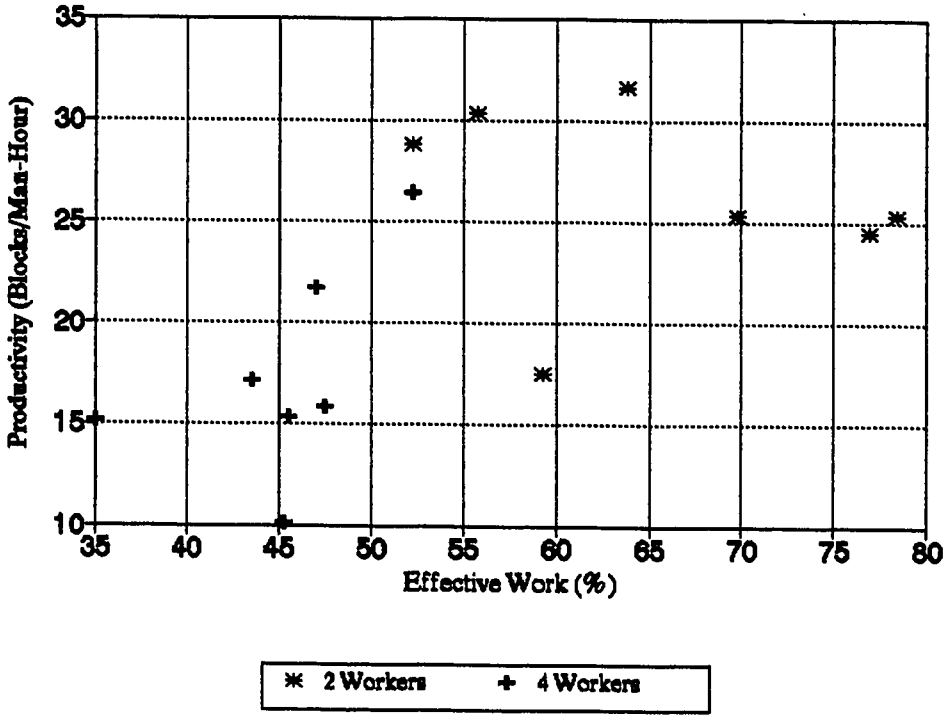

Figure 4.3 - Relationship Between Productivity And Effective Work Category For Two Workers, And Four Workers Crew Sizes

effective work.

The comparison between the two coefficients of correlation of 0.498 and 0.0021, using the Fisher's test, indicated that the crew size has a significant impact on the relationship between productivity and effective work category.

4.2.3 The Effect Of Skill Level On The Relationship

The effect of skill level on the relationship between productivity and effective work was investigated using both experimental and statistical controls. The results of these two techniques are presented below.

4.2.3.1 Experimental Control

Two groups of data having the same crew size and complexity level but different skill levels were used to investigate experimentally the effect of skill level on the relationship between productivity and effective work category. These two groups are of experiments 8 to 14 and experiments 29 to 35. The first group represents high skill level masons and the second one represents low skill level masons. Productivity was related to effective work category using these two groups of data, and this relation is shown in Figure 4.4. In this figure, The relationship between productivity and effective work is not clear.

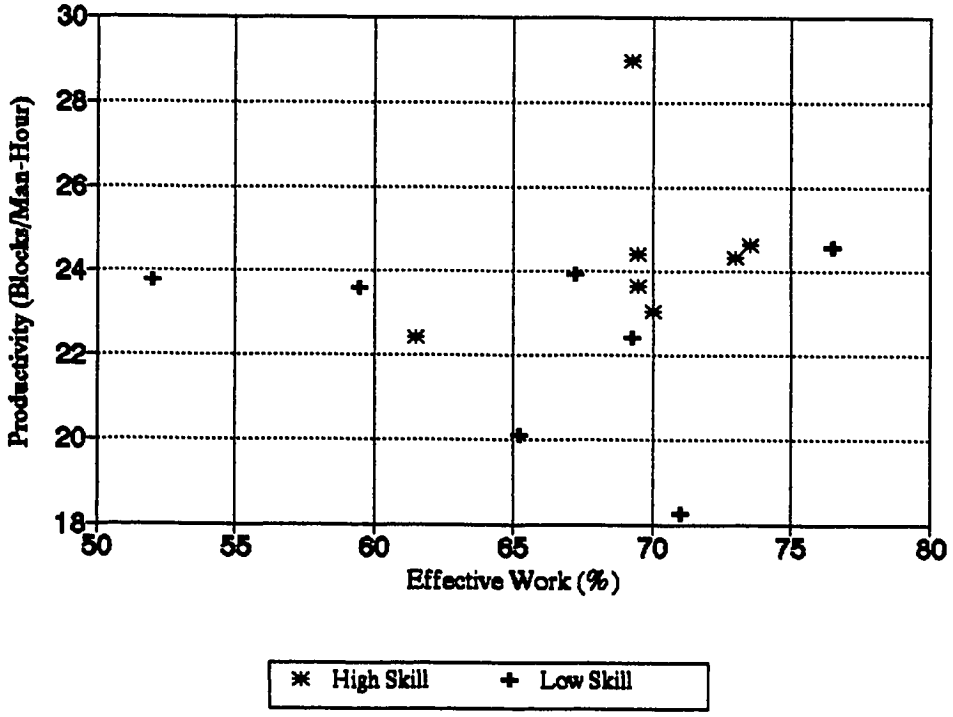

Figure 4.4 - Relationship Between Productivity And Effective Work Category For High, And Low Skill Levels

The coefficient of correlation of the data points 8 to 14 was found to be 0.290 (p= 0.53, N.S.). In addition, the coefficient of correlation of the data points 29 to 35 was found to be -0.189 (p = 0.69, N.S.).

The non significant correlations, though primarily due to the limited sample size, prevent any further analysis.

4.2.3.2 Statistical Control

The partial correlation between productivity and effective work while controlling the effect of skill level was 0.514 with a significance level less than 0.005. This shows a moderate positive relationship between productivity and effective work category.

A comparison between the coefficient of correlation before and after controlling the skill level, i.e. 0.498 versus 0.514, and using Fisher's test, shows that there is no difference between them.

This shows that there is no impact of skill level on the relationship between productivity and effective work.

4.2.4 Discussion

The previously presented results show that there is a positive moderate relationship between productivity and effective work category. In other words, the time spent in effective work category is directly related to productivity. This supports the first

hypothesis of this study.

However, the coefficient of correlation between productivity and effective work category is less than expected. The expectation was to find a stronger correlation between productivity and effective work category. The moderate correlation could have been caused by ignoring the essential contributory work category from the calculation. So, the contribution of this category was investigated by correlating productivity to the Labor Utilization Factor (LUF). The LUF is represented by the following formula (Oglesby, Parker, Howell, 1989);

$$LUF = EW + \frac{ECW}{4} \tag{11}$$

The coefficient of correlation between productivity and LUF is 0.542 with a significance level less than 0.005. This shows that the coefficient of correlation was improved when the essential contributory work was considered. However, using Fisher's test, the difference between the two coefficients of correlation is not significant. Furthermore, a linear regression model relating productivity to effective work and essential contributory work categories was developed. This model is presented here;

$$\text{Pr} = 2.482 + 0.252EW + 0.278ECW \tag{12}$$

This relationship has an adjusted coefficient of determination of 0.345, indicating that 34.5% of the variation in productivity is explained by EW and ECW. Even though this variation is less than expected, this model resulted in a correlation of 0.588 which is

higher than the one resulted from using EW alone. Also, Fisher's test showed a significant difference between 0.588 and 0.498.

Using the experimental control approach, the results show that it failed to indicate any significant effect of complexity level, crew size, and skill level on the relationship between productivity and effective work category. The results obtained using this approach, when showing negative correlations, are contradictory to the actual relationship between productivity and effective work category. This is may be due to the small number of data used for each group, and the restriction of the range of productivity (productivity varied from 16 to 32 blocks / man-hour). Also, it may be due to the artificial levels of skill and complexity. The complexity levels were designed by the researcher after consulting a group of masons about the complexity of their work. Also, the workers were evaluated by their leader. Based on this evaluation, two skill levels were considered. The researcher is confident that the people consulted provided him with true information, however, the results caused doubts of the degree of variation of complexity and skill levels. In addition, the evaluation was based on their experience and not on a scientific method, which may affected the accuracy of the information provided by them.

The use of statistical control, however, was successful in studying the effect of complexity level, crew size, and skill level on the relationship between productivity and effective work category. The results indicated that there is no effect of complexity level, and skill level on this relationship. However, the results showed that the crew size can affect the relationship, and that the relationship is stronger when the crew size is varying, but there is no relationship when the crew size is controlled.

Table 4.5 shows that both productivity and effective work category are negatively related to crew size. The relationship between crew size and effective work category is stronger than the relationship between crew size and productivity. However, the researcher believes that if more crew sizes (2, 4, 6 workers) were considered, better evaluation of the effect of crew size will be obtained.

Finally, the moderate association between effective work and productivity indicates that work sampling is not capable of providing the data necessary to predict productivity. Work sampling is able to provide the percentage of time at which the workers are engaged in effective work activities, however, it can not measure the effectiveness of these workers. In other words, there are many factors affecting productivity and one of them is the rate at which the effective activity is being executed. This rate is not considered by work sampling. Also, the points presented at the beginning of this discussion may raise the question about the appropriateness of using the coefficient of (1/4) for the essential contributory work category in the model of LUF. The ratio of coefficients of ECW to EW is (1.1). This suggested that a coefficient of (1/4) in the LUF is an underestimate of the contribution of ECW to productivity.

4.3 Relationship Between Productivity And Ineffective Work Category

The relationship between productivity and ineffective work category is shown in Figure 4.5. In this figure, 35 data points were used, the pattern of these data points indicates that there is a negative relationship between the two variables.

	Productivity	Effective Work	Essential Contributory Work	Ineffective Work	Complexity Level	Crew Size	Skill Level
Productivity	1						
Effective Work	0.498(a)	1					
Essential Contributory Work	0.203(*)	-0.297(*)	1				
Ineffective Work	-0.675(c)	-0.914(c)	0.035(*)	1			
Complexity Level	0.182(*)	0.464(a)	-0.032(*)	-0.500(a)	1		
Crew Size	-0.618(c)	-0.806(c)	0.121(*)	0.844(c)	-0.534(b)	1	
Skill Level	-0.053(*)	0.158(*)	-0.226(*)	-0.065(*)	0.134(*)	-0.25(*)	1

(a) Significant at =< 0.01

(b) Significant at =< 0.001

(c) Significant at =< 0.0001

(*) Not Significant

Table 4.5 - Coefficient Of Correlation Matrix Among All The Variables

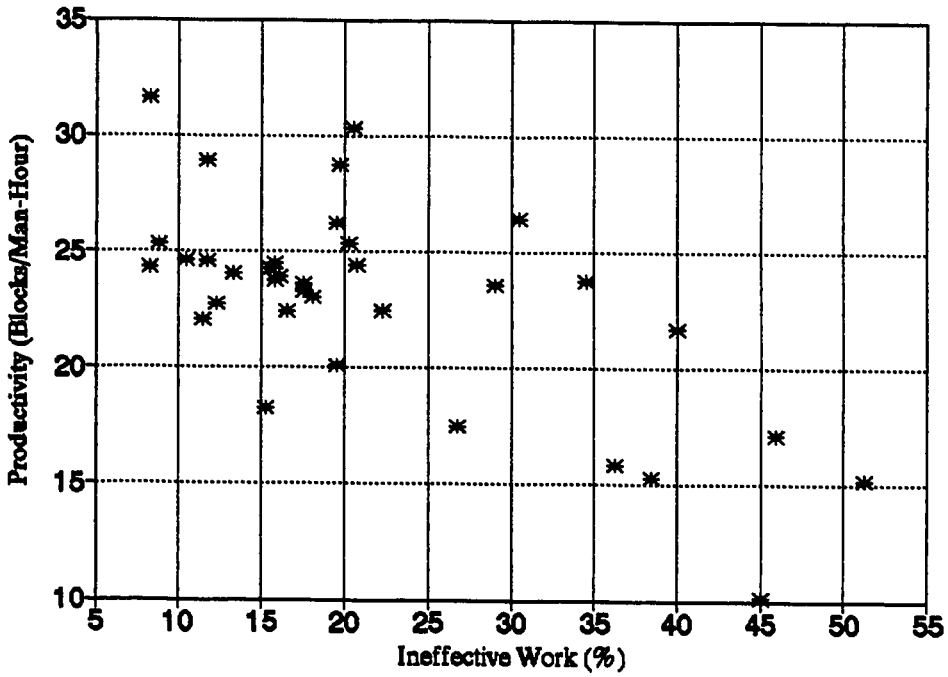

Figure 4.5 - Relationship Between Productivity And Ineffective Work Category For All Data Points

The coefficient of correlation between the two variables is -0.675 with a significance level of less than 0.005. This indicates a strong negative relationship between productivity and ineffective work.

The effect of complexity level, crew size, and skill level on the relationship was investigated, and the results are presented below.

4.3.1 The Effect Of Complexity Level On The Relationship

Two techniques were used to investigate the effect of complexity level on the relationship between productivity and ineffective work category. These techniques were the experimental and statistical controls. The results of using these two techniques are presented below.

4.3.1.1 Experimental Control

The relationship between productivity and ineffective work category was investigated experimentally, by comparing the coefficient of correlation between the two variables for three groups of data, having the same skill level and crew size but different complexity levels. These groups of data were data points of experiments 1 to 7, experiments 8 to 14, and experiments 15 to 21. Figure 4.6 shows the relationship between productivity and ineffective work category using these three groups of data. This figure shows that the different groups of data gave different forms of relationships.

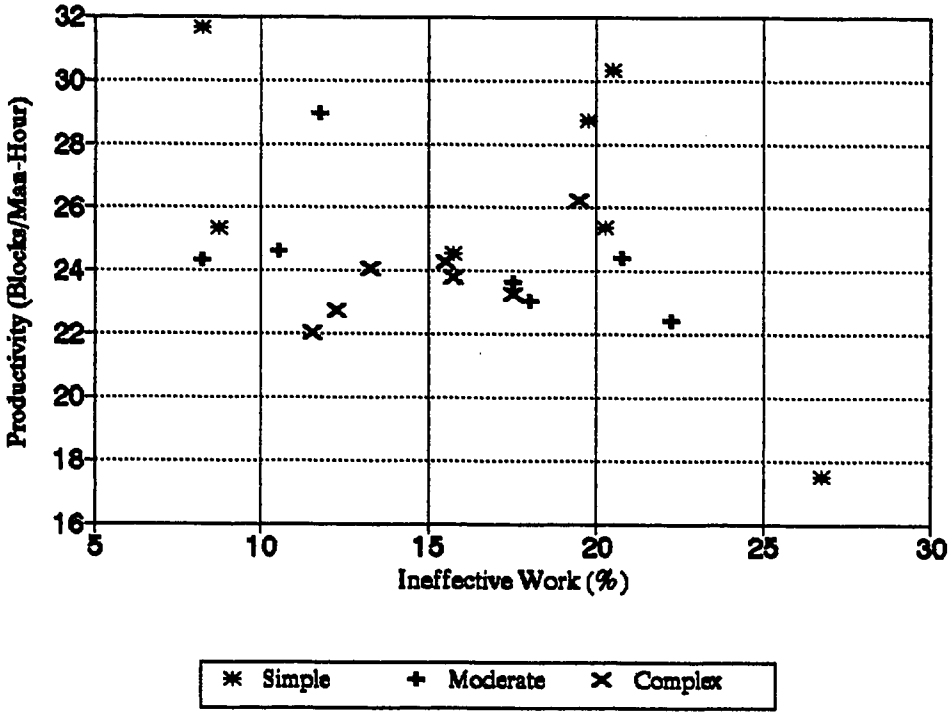

Figure 4.6 - Relationship Between Productivity And Ineffective Work Category For Simple, Moderate, And Complex Levels Of Complexity

The coefficient of correlation, r_{1-7} was found to be -0.549 (p = 0.201, N.S.), and r_{8-14} is -0.520 (p = 0.231, N.S.). Also, r_{15-21} is 0.797 with a significance level of 0.032. These coefficients of correlation can not be used to study the effect of complexity level on the relationship between productivity and ineffective work category. The different signs of the results implied that the experimental control was not an adequate method of finding the effect of complexity level on the relationship between productivity and ineffective work category. Also, the non significant coefficients of correlation prevent further investigation. So, the statistical control was used for that purpose.

4.3.1.2 Statistical Control

The statistical control of the complexity level, lead to -0.6807 correlation between productivity and ineffective work with a significance level less than 0.005. This indicates a strong negative relationship between productivity and ineffective work category.

In order to find the effect of complexity level on the relationship between productivity and ineffective work category, -0.675 was compared to -0.681 using Fisher's test, which indicated that there is no difference between them.

4.3.2 The Effect Of Crew Size On The Relationship

The effect of crew size on the relationship between productivity and ineffective work category was investigated using experimental and statistical controls. Both of these

techniques are presented below.

4.3.2.1 Experimental Control

The comparison of r_{1-7}, and r_{22-28} was used to study the effect of crew size on the relationship between productivity and ineffective work category. Both groups of data are presented in Figure 4.7. This figure shows that the two groups of data show a negative relationship between productivity and ineffective work category.

The coefficient of correlation, r_{1-7} is -0.549 ($p = 0.201$, N.S.), and r_{22-28} is -0.644 ($p = 0.118$, N.S.). Though the results are not statistically significant, these were the first logical results found using the experimental control. Using the Fisher's test, indicates that the difference between these two values is significant.

4.3.2.2 Statistical Control

When controlling the effect of crew size, the coefficient correlation between productivity and ineffective work was -0.366 ($p = 0.034$). This shows that there is a weak negative correlation between productivity and ineffective work category.

This impact is further investigated using the Fisher's test. The result indicates a significant effect of crew size on the relationship between productivity and ineffective work category.

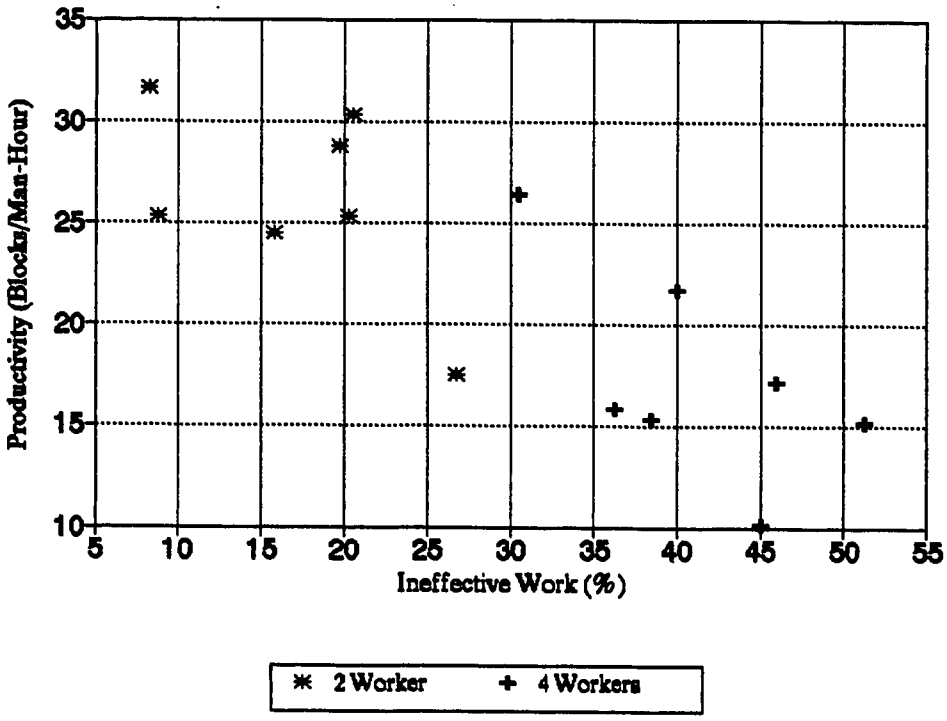

Figure 4.7 - Relationship Between Productivity And Ineffective Work Category For Two Workers, And Four Workers, Crew Sizes

4.3.3 The Effect Of Skill Level On The Relationship

The investigation of the effect of skill level on the relationship between productivity and ineffective work was made using experimental and statistical controls, and the results are presented in the following sections.

4.3.3.1 Experimental Control

The experimental investigation of the effect of skill level on the relationship between productivity and ineffective work category was made by comparing $r_{8\text{-}14}$ and $r_{29\text{-}35}$. Figure 4.8 shows the two groups while relating productivity to ineffective work. In this figure, the high skill level group of data shows negative relationship, and the data of low skill level does not portray a clear relationship.

The coefficient of correlation, $r_{8\text{-}14}$ is -0.520 ($p = 0.231$, N.S.), and $r_{29\text{-}35}$ is 0.237 ($p = 0.608$, N.S.). These results indicate a different nature of relationships for the two skill levels. No inferences can be obtained based on that data. So, statistical investigation of the effect of skill level on the relationship was made.

4.3.3.2 Statistical Control

The partial correlation between productivity and ineffective work while controlling the effect of skill level was -0.681 with a significance level less than 0.005.

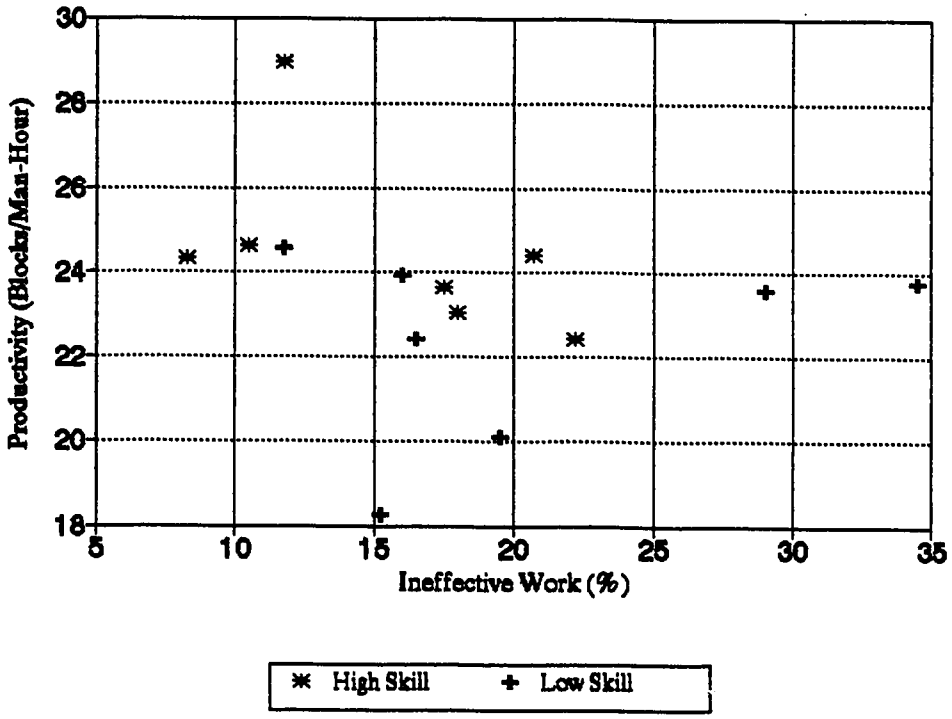

Figure 4.8 - Relationship Between Productivity And Ineffective Work Category For High, And Low Skill Levels

This showed a strong negative relationship between productivity and ineffective work category.

The comparison between the two coefficients of correlation, which are -0.675 and -0.681, and using the Fisher's test shows no effect of the skill level over the relationship between productivity and effective work.

4.3.4 Discussion

The previously presented results show that there is a strong negative relationship between productivity and ineffective work category. So, the time spent in ineffective work category is negatively related to productivity. This supports the second hypothesis of this study.

When compared to the results of previous section, the coefficient of correlation between ineffective work and productivity is found to be greater than the coefficient of correlation between effective work and productivity. This is logical, because while ineffective work is sufficient to lose productivity, effective work is necessary but not sufficient to gain productivity. So, ineffective work category is better predictor of productivity than effective work category.

In addition, the results show that experimental controls aimed at identifying the effect of complexity level, and skill level on the relationship between productivity and ineffective work category was not meaningful. On the other hand, the results showed no effect of crew size on the relationship. However, the non significant results of all cases

prevented further analysis.

On the other hand, the statistical control - based analysis of the effect of complexity level, crew size, and skill level show that there was no effect of complexity level, and skill level on the relationship between productivity and work sampling. However, the crew size can affect this relationship. The results showed that the control of the crew size will reduce the correlation between productivity and ineffective work category. This is similar to the effect of crew size on the relationship between productivity and ineffective work category. The same comments presented in Section 4.2.4 apply here.

4.4 Relationship Between Effective Work And Ineffective Work Category

Figure 4.9 shows the relationship between effective work category and ineffective work category. This figure shows 35 data points relating the two variables, and indicating a strong negative relationship.

The coefficient of correlation between the two variables is -0.914 with a significance level of less than 0.005. This indicates a very strong negative relationship between effective work and ineffective work categories.

This relationship was investigated under the influence of complexity level, crew size, and skill level as shown in the following sections.

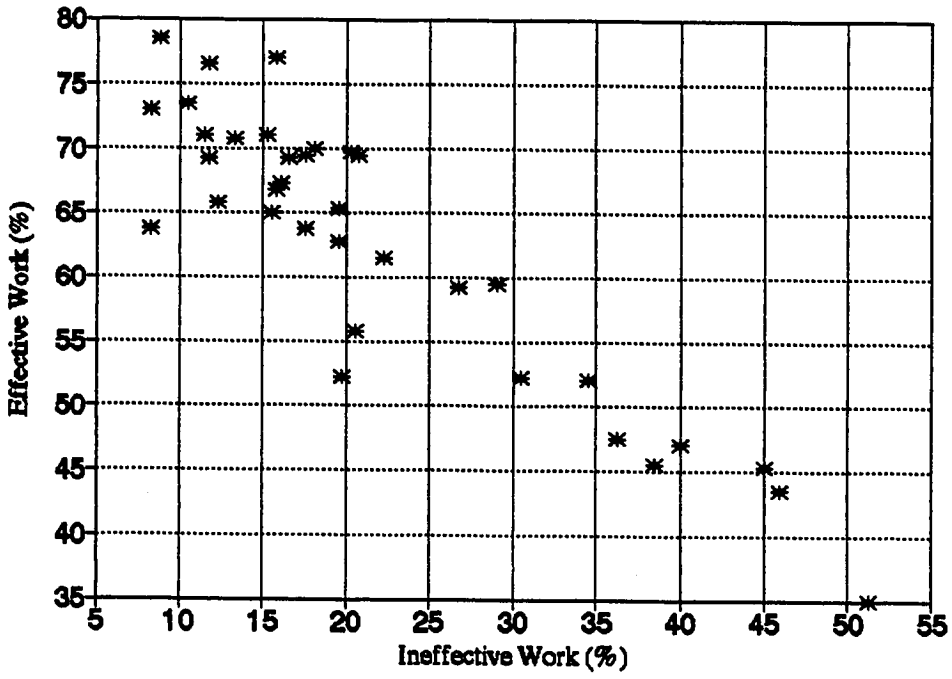

Figure 4.9 - Relationship Between Effective Work Category, And Ineffective Work Category For All Data Points

4.4.1 The Effect Of Complexity Level On The Relationship

The effect of complexity level on the relationship between effective work and ineffective work was investigated in two ways. Both experimental and statistical controls of complexity level were made to find its' effect on the relationship. The result of each approach is presented in the following two sections.

4.4.1.1 Experimental Control

The effect of complexity level on the relationship between effective work and Ineffective work was investigated through experimental control by comparing the following coefficients of correlation $r_{1\text{-}7}$,$r_{8\text{-}14}$, and $r_{15\text{-}21}$. Figure 4.10 presents the relationship between effective work and ineffective work for these three groups of data points. This figure shows that the two variables are negatively related in all three groups of data.

The coefficient of correlation of the data points of experiments 1 to 7 is -0.540 (p= 0.211, N.S.), and the coefficient of correlation of the data points of experiments 8 to 14 is -0.764 (p = 0.045, S.). In addition, the coefficient of correlation of the data of experiments 15 to 21 is -0.810 (p = 0.027, S.). Using the Fisher's test, the results indicate no significant difference between the last two coefficients of correlation. Although the first group of data shows a non significance correlation, the results indicate that complexity level does not affect the relationship between effective work and ineffective

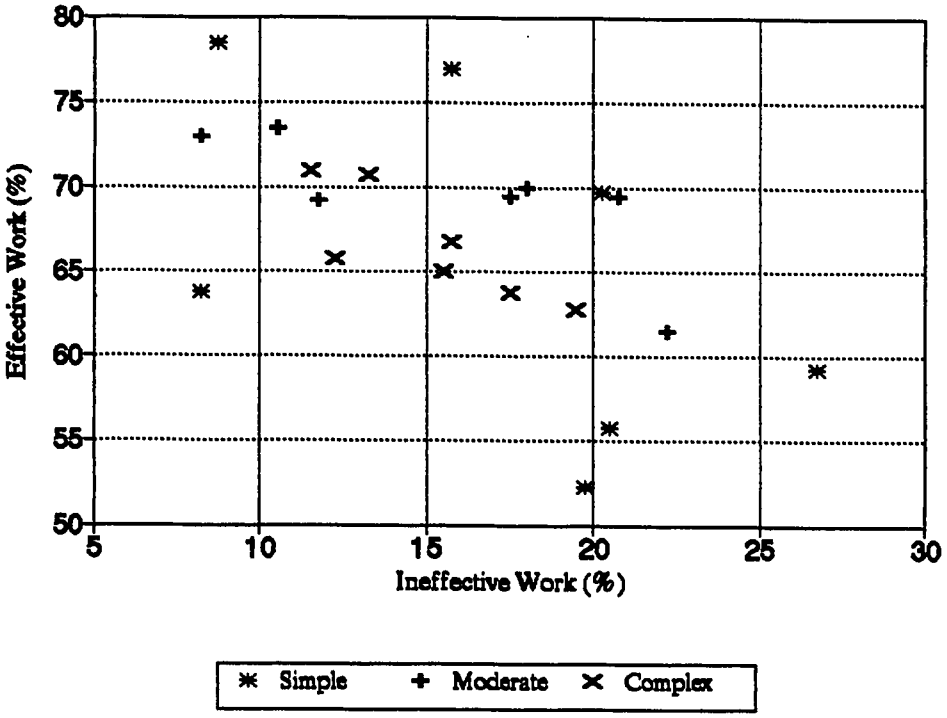

Figure 4.10 - Relationship Between Effective Work Category, And Ineffective Work Category For Simple, Moderate, And Complex Levels Of Complexity

work categories.

Beside experimental control, statistical control was made to study the effect of complexity on the relationship between effective work and ineffective work category.

4.4.1.2 Statistical Control

When controlling the effect of complexity level, the coefficient of correlation between effective work and ineffective work was -0.888 with a significance level less than 0.005. This indicates a very strong negative relationship between effective work category and ineffective work category.

The comparisons between the two coefficients of correlation that are -0.914 and -0.888 using Fisher's test indicates that there is no significant difference between the two coefficients of correlation. So, the statistical control of complexity level showed it has no effect over the relationship between effective work and ineffective work categories.

4.4.2 The Effect Of Crew Size On The Relationship

The effect of crew size on the relationship between effective work and ineffective work category was investigated using experimental and statistical controls. Both of these techniques are presented below.

4.4.2.1 Experimental Control

The comparison of r_{1-7}, and r_{22-28} were used to study the effect of crew size on the relationship between effective work and ineffective work category. Both groups of data are presented in Figure 4.11. This figure shows that the two groups of data show a negative relationship between effective and ineffective work categories.

In computations of the coefficient of correlation, r_{1-7} was found to be -0.540 ($p=0.211$, N.S.), and r_{22-28} was found to be -0.921 ($p = 0.003$, S.). Using Fisher's test, the comparison between -0.540, and -0.921 indicates a significant difference between the two coefficients of correlation. This indicates that the change in crew size did affect the relationship between effective work and ineffective work categories. This means that the larger the size of the crew the stronger the relationship, however, the non significance of the coefficient of correlation of experiments 1 to 7 downgrade the outcome of the experimental control approach.

4.4.2.2 Statistical Control

When controlling the effect of crew size, the coefficient correlation between effective and ineffective work was -0.735 with a significance level less than 0.005. This indicates a strong negative correlation between effective work category and ineffective work category.

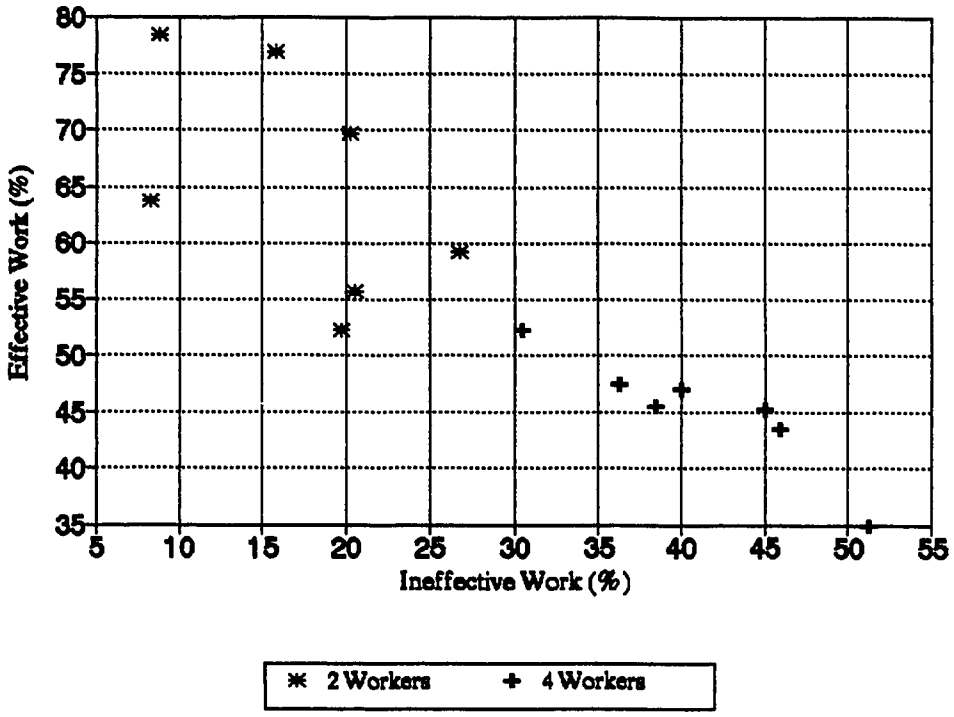

Figure 4.11 - Relationship Between Effective Work Category, And Ineffective Work Category For Two Workers, And Four Workers, Crew Sizes

The two coefficients of correlation which are -0.914 and -0.735 were compared to each other. Using the Fisher' test, indicates a significant difference between the two values. This shows that there is a noticeable effect of crew size on the relationship between effective work and ineffective work.

4.4.3 The Effect Of Skill Level On The Relationship

The effect of skill level on the relationship between effective work and ineffective work was investigated using both experimental and statistical controls. The results of these two techniques are presented in the following sections.

4.4.3.1 Experimental Control

The effect of skill level on the relationship between effective work and ineffective work was investigated through experimental control by comparing the two coefficients of correlation $r_{8\text{-}14}$, and $r_{29\text{-}35}$. The relationship between effective work and ineffective work for these two groups are shown in Figure 4.12. This figure shows a strong negative relationship between effective work category and ineffective work category.

The coefficient of correlation of the data points of experiments 8 to 14 is -0.763 (p= 0.046, S.). Also, the coefficient of correlation of the data points of experiments 29 to 35 is -0.974 (p = 0.005, S.).

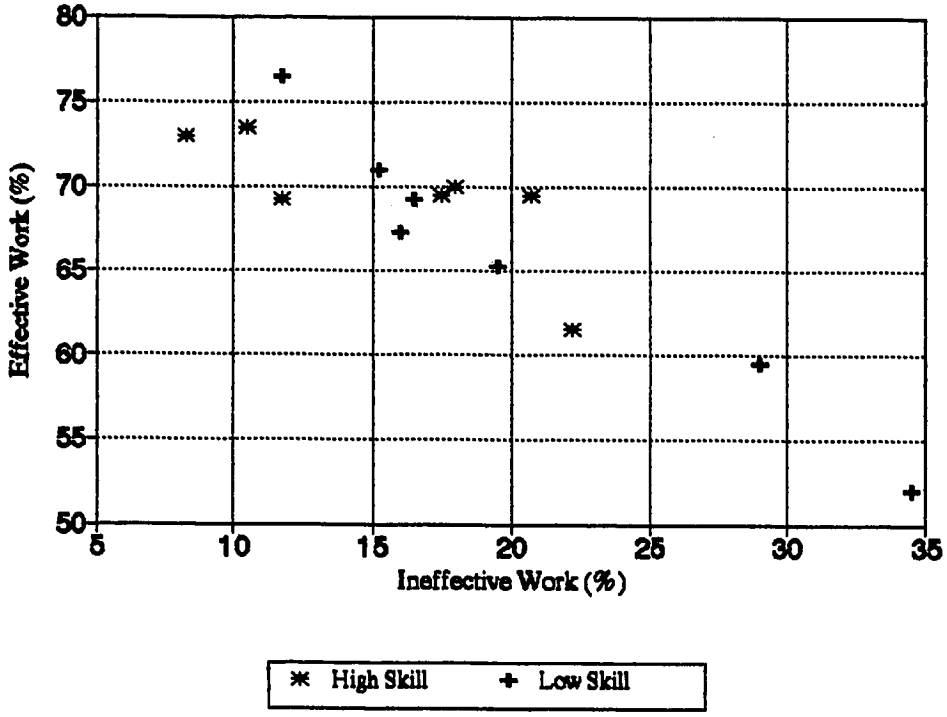

Figure 4.12 - Relationship Between Effective Work Category, And Ineffective Work Category For High, And Low Skill Levels

The use of Fisher test helped in comparing the two coefficients of correlation, and the results show no difference between the two correlations. This indicates that the skill level has no effect on the relationship between effective work and ineffective work categories.

4.4.3.2 Statistical Control

The partial correlation between effective and ineffective work while controlling the effect of skill level was -0.917 with a significance level less than 0.005. Using the Fisher's test, the comparison between the two coefficients of correlation shows no difference between the two values. Indicating that there is no effect of the skill level over the relationship between effective and ineffective work.

4.4.4 Discussion

The previously presented results showed that there is a very strong negative relationship between effective work and ineffective work categories. Although this result is partially due to the complementary nature of definitions of the two categories, the result supports the third hypothesis of this study.

In addition, both experimental and statistical controls were used to study the effect of complexity level, crew size, and skill level on the relationship between effective work and ineffective work categories. However, the experimental controls of these variables

provided different results from those of statistical controls. This difference in the results means that at least one of them is not accurate. Based on the results of sections 4.2, and 4.3, the experimental control failed in providing conclusive results, which is due to the small number of data points used for this approach. Although some of the results in this section were logical, they will not be used in the analysis, because the same approach failed in providing logical results in sections 4.2, and 4.3.

The results of the statistical control show that the relationship between effective work and ineffective work categories is not affected by any of the three variables which are complexity level, crew size, and skill level. Unlike the first two relationships, crew size does not show any effect on this one. Although this result contradict the nature of effect of crew size on the previous two relationships, it does not have great importance because the main concern is with the effect of crew size on the relationship between productivity and work sampling categories.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary

This thesis consists of an experimental study to investigate the use of work sampling as an indicator of construction labor productivity. Although, there were several studies made to investigate the relationship, the results were not consistent. The contradiction over the use of work sampling in productivity motivated the researcher to do this study.

The researcher decided to do field experiments in order to provide accurate data and to have a better control over the influencing variables. A total of 35 experiments were performed and filmed in this study. In these experiments, concrete masonry walls of three complexity levels were constructed. Six masons having two different skill levels participated in this study. These workers formed two different crew sizes, one with two workers and the other with four workers. All the observations were taken from the video taped experiments in order to avoid problems associated with field observations such as observer's fatigue. A total of 27 activities or work situations were identified and classified into the three categories of effective work, essential contributory work, and ineffective work. This classification of the activities was based on the definitions of these categories. Then, the strength of the relationships among productivity and work sampling

percentages was tested using the Pearson's coefficient of correlation. In addition, the effect of the three potentially influencing variables on the relationships was tested using both experimental control and statistical control approaches. The full description of the methodology followed in this study is presented in Chapter 3.

The results showed that, the coefficient of correlation between productivity and effective work category is 0.498, the coefficient of correlation between productivity and ineffective work category is -0.675, and the coefficient of correlation between effective work category and ineffective work category is -0.914. In addition, the results showed that the experimental control approach is not capable of providing meaningful results because of the limited number of data of each group. However, the use of the statistical control approach was successful, and the results showed that both complexity level and skill level do not affect the relationships. However, the crew size can affect the relationships. The results of this analysis is presented in Chapter 4.

The conclusions of this study is presented in the following section.

5.2 Conclusions

The major conclusions of this study are as follows:

1. The three hypotheses of the study were supported by the results. The results showed the following;

   a- There is a moderate positive relationship between productivity and effective work category.

b- There is a strong negative relationship between productivity and ineffective work category.

c- There is a very strong negative relationship between effective work and ineffective work categories.

So, the study shows that Thomas arguments are not totally accurate.

2. The study showed that the experimental control of the influencing variables gave a contradictory results. The researcher believes this is most likely due to the small sample size of the data and the limited levels or possibly the artificiality of the variation in complexity, skill, and crew size used in the experimental control approach.

3. The statistical control did not detect any significant effect of the levels of complexity, and skill used on the three relationships advanced by the hypotheses. However, it showed that the variation of crew size can affect the relationships. This effect could have been spurious due to the high correlation between crew size and effective work category. However, a better understanding of this effect could be obtained if more variation in the crew size was made.

4. The study showed that better prediction of productivity can be made using effective work and essential contributory work categories combined instead of effective work category alone. Also, the study showed that the relationship between productivity and labor utilization factor is stronger than the relationship between productivity and effective work category. However, the use of the coefficient of (1/4) is an underestimate of the effect of essential contributory work

in the formula of LUF.

5. Generally, work sampling does not provide highly accurate prediction of productivity, but it can be used for other purposes.

5.3 Recommendations

Based on the results and conclusions drawn from this study, recommendations of the application of work sampling and further research are presented in the following sections.

5.3.1 Recommendations On The Application Of Work Sampling

Results do not support using work sampling to measuring construction labor productivity, however, work sampling can be used to improve construction labor productivity in two ways:

1. Results of work sampling can be effectively used to estimate construction labor utilization i.e. what the workers are doing.
2. The percentages of ineffective work is useful to pinpoint potential trouble areas which will help management to focus on these areas and ways to correct them.

5.2.2 Recommendations For Further Research

The design of field experiment was the most sensitive research method for showing the relationship between productivity and work sampling. In spite of this, the relationship was moderate. There is no point of replicating the study using different crafts or arrangements. Future research should focus on two issues, which are:

1. Refining work sampling for measuring productivity, e.g. incorporate measuring the rate (speed) of worker and assess how this can affect predictive ability of work sampling.
2. Developing other techniques, which are not based on work sampling to measure productivity.

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APPENDIX A

Table Of Random Numbers

	00 04	05 09	10 14	15 19	20 24	25 29	30 34	35 39	40 44	45 49
00	39591	66082	48626	95780	55228	87189	75717	97042	19696	48613
01	46304	97377	43462	21739	14566	72533	60171	29024	77581	72760
02	99547	60779	22734	23678	44895	89767	18249	41702	35850	40543
03	06743	63537	24553	77225	94743	79448	12753	95986	78088	48019
04	69568	65496	49033	88577	98606	92156	08846	54912	12691	13170
05	68198	69571	34349	73141	42640	44721	30462	35075	33475	47407
06	27974	12609	77428	64441	49008	60489	66780	55499	80842	57706
07	50552	20688	02769	63037	15494	71784	70559	58158	53437	46216
08	74687	02033	98290	62635	88877	28599	63682	35566	03271	05651
09	49303	76629	71897	30990	62923	36686	96167	11492	90333	84501
10	89734	39183	52026	14997	15140	18250	62831	51236	61236	09179
11	74042	40747	02617	11346	01884	82066	55913	72422	13971	64209
12	84706	31375	67053	73367	95349	31074	36908	42782	89690	48002
13	83664	21365	28882	48926	45435	60577	85270	02777	06878	27561
14	47813	74854	73388	11385	99108	97878	32858	17473	07682	20166
15	00371	56525	38880	53702	09517	47281	15995	98350	25233	79718
16	81182	48434	27431	55806	25389	40774	72978	16835	65066	28732
17	75242	35904	73077	24537	81354	48902	03478	42867	04552	66034
18	96239	80246	07000	09555	55051	49596	44629	88225	28195	44598
19	82988	17440	85311	03360	38176	51462	86070	03924	84413	92363
20	77599	29143	89088	57593	60036	17297	30923	36224	46327	96266
21	61433	33118	53488	82981	44709	63655	64388	00498	14135	57514
22	76008	15045	45440	84062	52363	18079	33726	44301	86246	99727
23	26494	76598	85834	10844	56300	02244	72118	96510	98388	80161
24	46570	88558	77533	33359	07830	84752	53260	46755	36881	98535
25	73995	41532	87933	79930	14310	64833	49020	70067	99726	97007
26	93901	38276	75544	19679	82899	11365	22896	42118	77165	08734
27	41925	28215	40966	93501	45446	27913	21708	01788	81404	15119
28	80720	02782	24326	41328	10357	86883	80086	77138	57072	12100
29	92596	39416	50362	04423	04561	58179	54188	44978	14322	97056
30	39693	58559	45839	47278	38548	38885	19875	26829	86711	57005
31	86923	37863	14340	30929	04079	65274	03030	15106	09362	82972
32	99700	79237	18172	58879	56221	65644	33331	87502	32961	40996
33	60248	21953	52321	16984	03252	90433	97304	50181	71026	01946
34	29136	71987	03992	67025	31070	78348	47823	11033	13037	47732
35	57471	42913	85212	42319	92901	97727	04775	94396	38154	25238
36	57424	93847	03269	56096	95028	14039	76128	63747	27301	65529
37	56768	71694	63361	80836	30841	71875	40944	54827	01887	54822
38	70400	81534	02148	41441	26582	27481	84262	14084	42409	62950
39	05454	88418	48646	99565	36635	85496	18894	77271	26894	00889
40	80934	56136	47063	96311	19067	59790	08752	68040	85685	83076
41	06919	46237	50676	11238	75637	43086	95323	52867	06891	32089
42	00152	23997	41751	74756	50975	75365	70158	67663	51431	46375
43	88505	74625	71783	82511	13661	63178	39291	76796	74736	10980
44	64514	80967	33545	09582	86329	58152	05931	35961	70069	12142
45	25280	53007	99651	96366	49378	80971	10419	12981	70572	11575
46	71292	63716	93210	59312	39493	24252	54849	29754	41497	79228
47	49734	50498	08974	05904	68172	02864	10994	22482	12912	17920
48	43075	09754	71880	92614	99928	94424	86353	87549	94499	11459
49	15116	16643	03981	06566	14050	33671	03814	48856	41267	76252

50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99	
25178	77518	41773	39926	09843	29694	43801	69276	44707	23455	00
45803	95106	85816	33366	37383	76832	37024	06581	22587	24827	01
15532	30898	14922	13923	44987	45122	86515	55836	96165	19650	02
99068	35453	42152	12078	04913	06083	06645	93310	40016	85421	03
70983	88359	95583	79848	24101	67502	25692	42496	77732	19278	04
71181	48289	03153	18779	65702	03612	64608	84071	47588	09982	05
44052	59163	74033	86112	27731	46135	63092	59171	44816	12354	06
91555	87708	70964	43346	56811	08725	75139	77674	82467	41899	07
54307	12188	58089	73745	35569	97352	77301	37684	36823	69218	08
63631	23919	06785	13891	89918	76211	09362	34292	17640	65907	09
46832	30801	98898	28954	97793	20825	36775	71974	15574	09184	10
05944	82632	39310	74857	61725	50569	81937	16820	85446	51168	11
28199	90116	59501	49025	73005	84954	11587	97691	90415	84685	12
08391	05600	00624	95068	33776	44985	01505	76911	45539	32181	13
29634	13021	96568	15124	55092	44043	31073	92371	51288	33378	14
61509	18842	79201	46451	68594	98120	68110	91062	42095	61839	15
87888	23033	69837	65661	15130	44649	42515	83861	50721	36110	16
94585	15218	74838	61809	92293	85400	46934	08531	70107	65707	17
82033	93915	34898	79913	70013	27573	39256	35167	35070	47095	18
79131	10022	82199	78976	22702	37936	10445	96846	84927	69745	19
79344	39236	41333	11473	15049	47930	99029	97150	82275	55149	20
15384	44585	18773	89733	40779	59664	83328	25162	58758	17761	21
38802	90957	32910	97485	10358	88588	95310	22252	19143	69011	22
85874	18400	28151	29541	63706	43197	65726	94117	22169	91806	23
26200	72680	12364	46010	92208	59103	60417	45389	56122	85353	24
13772	75282	81418	42188	66529	47981	92548	10079	68179	40915	25
91876	07434	96946	98382	97374	34444	17992	42811	01579	48741	26
31721	21713	83632	40605	24227	53219	05482	86768	53239	24812	27
92570	53242	98133	84706	78048	29645	79336	66091	05793	25922	28
02880	29307	73734	66448	64739	74645	29562	13999	17492	49891	29
80982	14684	31038	85302	98349	57313	86371	33938	10768	60837	30
38000	43364	94825	32413	46781	09685	69058	56644	85531	55173	31
14218	94289	79484	61868	40034	22546	68726	14736	89844	13466	32
74358	21940	40280	22233	09123	49375	55094	46113	54046	51771	33
39049	14986	94000	26649	13037	34609	45186	89515	63214	66886	34
48727	06300	91486	67316	84576	11100	37580	49629	83224	46321	35
22719	29784	40682	96715	40745	57458	70048	48306	50270	87424	36
33980	36769	51977	03689	79071	20279	64787	48877	44063	93733	37
23885	66721	16542	12648	65986	43104	45583	75729	35118	58742	38
85190	44068	78477	69133	58983	96504	44232	74809	25266	73872	39
33453	36333	45814	78128	55914	89829	43251	41634	48488	49153	40
98236	11489	97240	01678	30779	75214	80039	68895	95271	19654	41
21295	53563	43609	48439	87427	88065	09892	58524	43815	31340	42
28335	79849	69842	71669	38770	54445	48736	03242	83181	85403	43
95449	35273	62581	85522	35813	34475	97514	72839	10387	31649	44
88167	03878	89405	55461	73248	48620	31732	47317	06252	54652	45
86131	62596	98785	02360	54271	26242	93735	20752	17146	18315	46
71134	90264	30126	08586	97497	61678	81940	00907	39096	02082	47
02664	53438	76839	52290	77999	05799	93744	16634	84924	31344	48
90664	96876	16663	25608	67140	84619	67167	13192	81774	58619	49

	00 04	05 09	10 14	15 19	20 24	25 29	30 34	35 39	40 44	45 49
50	93873	86558	72524	02542	73184	37905	05882	15596	73646	50798
51	08761	47547	02216	48086	56490	89959	69975	04500	23779	76697
52	61270	98773	40298	26077	80396	08166	35723	61933	13985	19102
53	73758	15578	95748	02967	35122	36539	72822	68241	34803	42457
54	17132	32196	60523	00544	73700	70122	27962	85597	36011	79971
55	26175	29794	44838	84414	82748	22246	70694	57953	39780	17791
56	06004	04516	06210	03536	84451	30767	37928	26986	07396	64611
57	34687	73753	36327	73704	61564	99434	90938	03967	97420	19913
58	27865	08255	57859	04746	79700	68823	16002	58115	07589	12675
59	89423	51114	90820	26786	77404	05795	49036	34686	98767	32284
60	99030	80312	69745	87636	10058	84834	89485	08775	19041	61375
61	02852	54339	45496	20587	85921	06763	68873	35367	42627	54973
62	10850	42788	94737	74549	74296	13053	46816	32141	02533	25648
63	38301	18507	33151	69434	80103	02603	61110	89395	67621	67025
64	48181	95478	62739	90148	00156	09338	44558	53271	87549	45974
65	23098	23720	76508	69083	56584	90423	21634	35999	09234	95116
66	25104	82019	21120	06165	44324	77577	15774	41091	69687	67576
67	22205	40198	86884	28103	57306	54915	03426	66700	45993	36668
68	64975	05064	29617	40622	20330	18518	45312	57921	23188	82361
69	58710	75278	47730	26093	16436	38868	76861	85914	14162	21984
70	12140	72905	26022	07675	16362	34504	47740	39923	04081	03162
71	73226	39840	47958	97249	14146	34543	76162	74158	59739	67447
72	12320	86217	66162	70941	58940	58006	80731	66680	02183	94678
73	41364	64156	23000	23188	64945	33815	32884	76955	56574	61666
74	97881	80867	70117	72041	03554	29087	19767	71838	80545	61402
75	88295	87271	82812	97588	09960	06312	03050	77332	25977	18385
76	95321	89836	78230	46037	72483	87533	74571	88859	26908	55626
77	24337	14264	30185	36753	22343	81737	62926	76494	93536	75502
78	00718	66303	75009	91431	64245	61863	16738	23127	89435	45109
79	38093	10328	96998	91386	34967	40407	48380	09115	59367	49596
80	87661	31701	29974	56777	66751	35181	63887	95094	20056	84990
81	87142	91818	51857	85061	17890	39057	44506	00969	32942	54794
82	60634	27142	21199	50437	04685	70252	91453	75952	66753	50664
83	73356	64431	05068	56334	34487	78253	67684	69916	63885	88491
84	29889	11378	65915	66776	95034	81447	98035	16815	68432	63020
85	48257	36438	48479	72173	31418	14035	84239	02032	40409	11715
86	38425	29462	79880	45713	90049	01136	72426	25077	64361	94284
87	48226	31868	38620	12135	28346	17552	03293	42618	44151	78438
88	80189	30031	15435	76730	58565	29817	36775	64007	47912	16754
89	33208	33475	95219	29832	74569	50667	90569	66717	46958	04820
90	19750	48564	49690	43352	53884	80125	47795	99701	06800	22794
91	62820	23174	71124	36040	34873	95650	79059	23894	58534	78296
92	95737	34362	81520	79481	26442	37826	76866	01580	83713	94272
93	64642	62961	37566	41064	69372	84369	92823	91391	61056	44495
94	77636	60163	14915	50744	95611	99346	39741	04407	72940	87936
95	43633	52102	93561	31010	11299	52661	79014	17910	88492	60753
96	93686	41960	61280	96529	52924	87371	34855	67125	40279	10186
97	23775	33402	28647	42314	51213	29116	26243	40243	32137	25177
98	91325	64698	58868	63107	08993	96000	66854	11567	80604	72299
99	58129	44367	31924	73586	24422	92799	28963	36444	01315	10226

50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99	
37686	78520	31209	83677	99115	94024	09286	58927	24078	16770	50
58108	29344	11825	51955	50618	99753	02200	50503	32466	50055	51
71545	42326	66429	93607	55276	85482	24449	41764	19884	46443	52
93303	90557	79166	90097	01627	96690	77434	06402	05379	59549	53
36731	37929	13079	83036	31525	35811	59131	65257	03731	86703	54
49781	31581	80391	84608	23390	30433	08240	85136	80060	43651	55
65995	94208	68785	04370	44192	91852	01129	28739	08705	54538	56
19663	09309	02836	10223	90814	92786	96747	46014	54765	76001	57
88479	24307	63812	47615	17220	27942	11785	49933	03923	35432	58
95407	95006	95421	20811	76761	47475	58865	06204	36543	81002	59
22789	87011	61926	97996	10604	80855	48714	52754	98279	96467	60
96783	18403	36729	18760	30810	73087	94565	68682	15792	60020	61
68933	05665	12264	23954	01583	75411	04460	83939	66528	22576	62
68794	13000	20066	98963	93483	51165	63358	12373	13877	37580	63
40537	31604	60323	51235	65546	85117	15647	09617	73520	48525	64
41249	42504	91773	81579	02882	74657	73765	10932	74607	83825	65
03813	84525	30329	33144	76884	89996	07834	67266	96820	15128	66
46609	30917	29996	10848	39555	09233	58988	82131	69232	76762	67
68543	69424	92072	57937	05563	80727	67053	35431	00881	56541	68
09926	84219	30089	08843	24998	27105	18397	79071	40738	73876	69
30515	76316	49597	37900	98604	05857	51729	19006	15239	27129	70
21611	26346	04877	71584	55724	39616	64648	36811	60915	34108	71
47410	83767	56454	96768	27001	83712	01245	27256	57991	75758	72
18572	31214	41015	64110	61807	72472	78059	69701	78681	17356	73
28078	02819	02459	33308	96540	15817	78694	81476	87856	99737	74
56644	50430	34562	75842	67724	02918	55603	55195	88219	39676	75
27331	48055	18928	47763	61966	64507	06559	81329	29481	03660	76
32080	21524	32929	07739	00836	39497	94476	27433	96857	52987	77
27027	69762	65362	90214	89572	52054	43067	73017	87664	03293	78
56471	68839	09969	45853	72627	71793	49920	64544	71874	74053	79
22689	19799	18870	49272	74783	38777	76176	40961	18089	32499	80
71263	82247	66684	90239	67686	48963	30842	59354	33551	87966	81
64084	57386	89278	27187	52142	96305	87393	80164	95518	82742	82
23121	10194	09911	37062	43446	09107	47156	70179	00858	92326	83
78906	48080	76745	65814	51167	87755	66884	12718	14951	47937	84
87257	26005	21544	37223	53288	72056	96396	67099	49416	91891	85
39529	98126	33694	29025	94308	24426	63072	51444	04718	49891	86
89632	11606	87159	89408	06295	31055	15530	46432	49871	37982	87
23708	98919	14407	53722	58779	92849	04176	24870	56688	25405	88
51445	46758	42024	27940	64237	10086	95601	53923	85209	79385	89
23849	65272	24743	39960	27313	99925	29743	87270	05773	21797	90
78613	15441	34568	57398	25872	61792	94599	60944	90908	38948	91
90694	27996	94181	87428	41135	29461	72716	68956	67871	72459	92
96772	86829	36403	40087	67456	21071	39039	91937	45280	00066	93
24527	40701	56894	73327	00789	97573	09303	41704	05772	95372	94
31596	70876	46807	06741	29352	23829	52465	00336	24155	61871	95
31613	99249	17260	05242	19535	52702	64761	66694	06150	13820	96
02911	09514	50864	80622	20017	59019	43450	75942	08567	40547	97
02484	74068	04671	19616	41951	05111	34013	57443	87481	48994	98
69259	75535	73007	15236	01572	44870	53280	25132	70276	87334	99

APPENDIX B

Time Instants And Activities Observed For Five Samples Of The Experiments (Exp. # 1, 8, 15, 22, 29)

This appendix includes experiments of six columns (Exp. # 1, 8, 15, 29), or eight columns (Exp.# 22). The first column represent the number of instant of time at which the observations were taken. The second, third, and forth columns represent the time in hours, minutes, and seconds respectively. The rest of columns represent the activities or work situations observed at that instant of time.

EXP.#1

	Time			Activity Observed	
	Hr.	Min.	Sec.	Obs.#1	Obs.#2
1	0	0	19	1	2
2	0	0	34	4	3
3	0	1	14	3	6
4	0	1	19	3	5
5	0	1	23	1	5
6	0	2	1	3	4
7	0	2	2	3	4
8	0	2	3	3	4
9	0	2	15	1	4
10	0	2	25	1	4
11	0	2	37	7	4
12	0	2	59	1	6
13	0	3	2	5	3
14	0	3	29	7	8
15	0	3	60	3	5
16	0	4	55	5	9
17	0	5	27	1	5
18	0	5	54	7	5
19	0	6	51	7	5
20	0	7	30	7	7
21	0	7	32	7	7
22	0	8	53	10	3
23	0	9	28	10	7
24	0	9	29	2	3
25	0	10	19	12	5
26	0	10	31	12	5
27	0	11	15	3	5
28	0	12	24	7	5
29	0	14	42	3	5
30	0	15	42	7	5
31	0	15	58	5	7
32	0	16	31	5	5
33	0	16	47	7	5
34	0	17	16	7	5
35	0	17	17	7	5
36	0	18	16	7	7
37	0	18	25	10	13
38	0	18	58	4	3
39	0	19	0	3	4
40	0	19	11	3	4
41	0	19	36	10	7
42	0	19	46	7	5
43	0	19	47	7	4
44	0	20	9	7	5
45	0	20	39	7	5
46	0	21	14	3	5

47	0	22	17	7	5
48	0	22	54	3	5
49	0	23	3	3	8
50	0	23	4	3	8
51	0	23	29	8	1
52	0	23	33	8	3
53	0	23	58	3	8
54	0	24	50	5	5
55	0	25	17	3	8
56	0	25	31	3	8
57	0	25	54	7	5
58	0	27	59	7	10
59	0	28	2	4	12
60	0	28	16	4	12
61	0	28	53	3	2
62	0	29	3	7	11
63	0	29	10	15	15
64	0	29	26	7	5
65	0	29	39	7	5
66	0	30	4	7	5
67	0	30	24	7	5
68	0	30	55	3	5
69	0	31	25	7	5
70	0	32	26	3	4
71	0	32	27	3	4
72	0	33	1	5	1
73	0	33	9	3	5
74	0	33	20	7	5
75	0	33	21	7	5
76	0	35	25	5	7
77	0	35	50	5	7
78	0	36	14	5	7
79	0	36	31	7	7
80	0	36	36	7	7
81	0	37	17	7	7
82	0	37	32	7	7
83	0	37	41	7	7
84	0	37	48	7	7
85	0	38	30	3	7
86	0	39	11	7	10
87	0	39	58	5	7
88	0	40	46	7	5
89	0	40	47	7	5
90	0	41	17	8	3
91	0	42	47	5	3
92	0	43	14	3	5
93	0	43	21	5	3
94	0	44	31	3	5

95	0	46	25	3	5
96	0	46	51	3	5
97	0	47	22	5	7
98	0	47	47	5	7
99	0	48	36	5	7
100	0	48	44	5	7
101	0	50	6	7	7
102	0	51	22	7	7
103	0	52	30	7	5
104	0	53	9	5	5
105	0	53	12	9	10
106	0	53	22	12	10
107	0	56	4	7	5
108	0	56	31	7	14
109	0	58	13	5	7
110	0	58	24	5	7
111	0	58	25	5	7
112	0	60	36	3	5
113	0	60	38	3	5
114	1	0	4	1	8
115	1	0	17	7	8
116	1	1	15	5	1
117	1	1	47	5	7
118	1	1	51	5	3
119	1	2	17	11	3
120	1	2	28	5	3
121	1	2	47	5	3
122	1	2	57	5	3
123	1	4	26	14	14
124	1	4	38	7	5
125	1	4	53	7	7
126	1	5	5	5	10
127	1	5	29	5	3
128	1	9	0	10	3
129	1	9	8	7	2
130	1	9	26	3	2
131	1	9	54	14	3
132	1	10	22	15	14
133	1	10	60	5	3
134	1	11	25	1	14
135	1	11	28	1	14
136	1	11	33	1	14
137	1	11	35	1	14
138	1	11	36	1	14
139	1	12	2	15	7
140	1	12	16	7	15
141	1	12	20	15	7
142	1	12	25	7	5

143	1	13	12	8	3
144	1	13	22	15	3
145	1	13	24	15	3
146	1	13	30	15	3
147	1	13	44	1	8
148	1	14	18	5	7
149	1	14	28	7	5
150	1	15	2	4	7
151	1	15	29	5	3
152	1	16	14	5	3
153	1	16	24	3	5
154	1	17	1	5	7
155	1	17	22	3	5
156	1	17	23	3	5
157	1	17	34	1	5
158	1	17	37	5	7
159	1	18	39	3	5
160	1	18	49	3	5
161	1	19	37	7	7
162	1	20	18	5	7
163	1	20	21	5	7
164	1	20	59	7	7
165	1	20	60	7	7
166	1	21	5	7	7
167	1	22	19	7	7
168	1	23	23	15	5
169	1	23	52	15	15
170	1	23	60	15	15
171	1	24	18	15	15
172	1	24	30	15	15
173	1	24	33	15	15
174	1	24	48	15	15
175	1	25	2	15	15
176	1	25	9	15	15
177	1	25	12	15	15
178	1	25	21	15	15
179	1	25	55	15	15
180	1	26	2	15	15
181	1	26	30	15	15
182	1	27	21	15	5
183	1	28	24	15	15
184	1	29	39	15	15
185	1	30	5	15	15
186	1	30	10	15	15
187	1	30	15	15	15
188	1	30	38	15	15
189	1	31	1	15	15
190	1	31	2	15	15
191	1	31	11	15	15
192	1	31	34	14	14
193	1	32	5	15	15
194	1	32	7	15	15
195	1	32	39	14	14
196	1	33	6	15	15

197	1	33	18	15	15
198	1	33	24	15	15
199	1	34	58	14	14
200	1	36	0	15	15

EXP.#8

	Time			Activity	Observed
	Hr.	Min.	Sec.	Obs.#1	Obs.#2
1	0	2	4	1	10
2	0	3	14	3	5
3	0	3	16	3	5
4	0	3	18	3	5
5	0	3	21	3	5
6	0	4	13	8	3
7	0	5	4	1	10
8	0	5	31	2	7
9	0	6	6	3	5
10	0	6	23	5	3
11	0	6	31	1	8
12	0	7	2	7	7
13	0	7	3	7	7
14	0	8	12	3	5
15	0	8	14	3	5
16	0	8	40	3	5
17	0	8	52	2	3
18	0	9	43	19	19
19	0	9	54	1	19
20	0	10	9	5	5
21	0	10	12	11	11
22	0	10	19	5	7
23	0	10	20	12	5
24	0	10	23	7	5
25	0	10	34	12	5
26	0	10	58	7	5
27	0	11	15	5	7
28	0	11	20	7	5
29	0	11	32	1	5
30	0	11	59	12	5
31	0	12	12	5	7
32	0	12	18	7	5
33	0	12	21	5	7
34	0	12	42	8	7
35	0	13	14	8	7
36	0	13	23	5	7
37	0	14	22	14	3
38	0	14	36	3	14
39	0	14	50	1	5
40	0	15	5	3	5
41	0	15	16	3	8
42	0	15	32	7	8
43	0	15	37	8	7
44	0	16	32	12	4
45	0	16	36	2	1
46	0	16	43	7	10

47	0	16	52	3	6
48	0	17	20	10	3
49	0	17	48	3	10
50	0	19	7	12	4
51	0	19	28	5	12
52	0	19	48	12	5
53	0	20	11	12	5
54	0	22	22	5	18
55	0	23	16	7	5
56	0	24	1	3	5
57	0	24	52	8	1
58	0	25	16	7	8
59	0	25	18	3	5
60	0	25	20	8	7
61	0	25	25	8	7
62	0	26	29	1	5
63	0	26	53	5	5
64	0	27	49	4	7
65	0	28	59	3	5
66	0	29	34	3	5
67	0	29	54	8	3
68	0	30	38	3	8
69	0	32	14	3	5
70	0	32	29	5	7
71	0	33	6	7	7
72	0	33	10	7	7
73	0	33	11	7	7
74	0	34	24	3	10
75	0	34	39	3	10
76	0	35	1	8	1
77	0	35	6	8	12
78	0	35	23	8	12
79	0	35	24	8	12
80	0	35	53	1	8
81	0	36	6	7	8
82	0	37	23	3	5
83	0	39	8	3	10
84	0	39	26	3	2
85	0	39	28	3	2
86	0	39	31	1	10
87	0	39	33	10	1
88	0	39	51	5	3
89	0	41	7	7	5
90	0	41	13	7	5
91	0	41	37	7	5
92	0	42	52	7	7
93	0	43	15	15	15
94	0	43	26	7	5
95	0	44	27	8	3
96	0	45	3	1	15
97	0	45	22	7	15
98	0	46	15	8	7
99	0	48	56	3	5
100	0	49	18	15	3

101	0	49	34	3	15
102	0	50	15	3	15
103	0	50	38	1	15
104	0	51	31	1	8
105	0	52	7	7	5
106	0	53	7	15	5
107	0	54	49	7	7
108	0	58	52	3	5
109	0	59	12	3	2
110	0	59	30	3	5
111	1	0	31	5	3
112	1	0	56	3	5
113	1	1	2	1	5
114	1	1	4	1	5
115	1	2	7	12	5
116	1	2	17	1	5
117	1	2	18	1	5
118	1	2	19	1	5
119	1	2	20	1	5
120	1	2	55	5	7
121	1	3	3	7	5
122	1	3	23	15	7
123	1	3	24	15	7
124	1	3	31	15	5
125	1	4	37	15	7
126	1	4	52	7	15
127	1	5	53	7	15
128	1	6	1	15	15
129	1	6	11	15	15
130	1	6	28	15	7
131	1	6	29	15	7
132	1	6	30	15	7
133	1	6	33	7	14
134	1	7	14	14	3
135	1	7	16	3	14
136	1	7	26	3	14
137	1	7	27	3	14
138	1	7	31	3	14
139	1	8	16	17	7
140	1	8	27	8	7
141	1	8	36	15	7
142	1	9	21	5	15
143	1	9	40	3	5
144	1	9	55	3	5
145	1	10	40	3	5
146	1	10	43	10	3
147	1	10	59	3	4
148	1	11	3	1	2
149	1	11	8	6	5
150	1	11	10	7	5
151	1	11	11	7	5
152	1	11	13	5	7
153	1	11	15	15	5
154	1	11	25	4	3

155	1	11	48	3	8
156	1	12	22	15	3
157	1	12	24	3	5
158	1	12	27	3	15
159	1	12	32	3	15
160	1	12	42	3	15
161	1	12	55	1	15
162	1	13	5	3	15
163	1	13	6	3	15
164	1	13	12	3	15
165	1	13	36	3	15
166	1	13	44	3	15
167	1	13	45	3	15
168	1	14	17	1	15
169	1	14	24	7	15
170	1	14	25	7	15
171	1	14	32	15	5
172	1	14	35	15	15
173	1	14	46	15	15
174	1	14	58	15	15
175	1	15	5	15	7
176	1	15	6	15	7
177	1	15	12	15	7
178	1	15	18	15	7
179	1	15	19	15	7
180	1	15	54	5	15
181	1	16	10	5	7
182	1	16	50	3	5
183	1	17	3	7	5
184	1	17	9	7	7
185	1	17	19	7	7
186	1	17	33	7	7
187	1	17	43	7	7
188	1	17	44	7	7
189	1	17	45	7	7
190	1	18	6	15	15
191	1	18	7	15	15
192	1	18	21	15	15
193	1	18	29	15	15
194	1	18	31	15	15
195	1	19	9	15	15
196	1	19	36	15	15
197	1	20	15	15	15
198	1	20	27	15	15
199	1	21	26	15	15
200	1	22	24	15	15

EXP.#15

	Time			Activity	Observed
	Hr.	Min.	Sec.	Obs.#1	Obs.#2
1	0	0	15	7	5
2	0	3	8	3	5
3	0	4	27	3	10
4	0	4	42	15	5
5	0	4	54	3	5
6	0	5	43	10	3
7	0	5	47	5	3
8	0	5	55	5	3
9	0	6	45	3	8
10	0	8	5	7	7
11	0	9	4	3	16
12	0	9	17	5	3
13	0	9	20	16	3
14	0	9	57	3	23
15	0	10	8	5	3
16	0	10	9	5	3
17	0	11	21	8	7
18	0	12	1	1	10
19	0	12	16	1	10
20	0	13	17	15	11
21	0	13	40	7	15
22	0	14	45	1	15
23	0	15	7	7	15
24	0	16	6	1	15
25	0	16	36	5	5
26	0	16	46	1	5
27	0	16	56	1	5
28	0	17	23	1	5
29	0	19	26	1	5
30	0	20	4	7	6
31	0	20	23	7	10
32	0	22	21	3	15
33	0	22	25	3	15
34	0	22	52	3	15
35	0	23	0	3	15
36	0	23	37	8	3
37	0	23	39	8	3
38	0	23	52	1	8
39	0	24	12	8	7
40	0	24	49	25	8
41	0	24	56	3	9
42	0	26	57	3	15
43	0	27	11	3	15
44	0	27	21	3	15
45	0	28	3	15	1
46	0	28	43	3	15

47	0	29	5	15	11
48	0	30	36	25	8
49	0	30	39	3	8
50	0	31	50	15	7
51	0	32	6	7	15
52	0	33	34	1	10
53	0	34	18	7	7
54	0	34	41	7	5
55	0	34	51	3	5
56	0	34	60	3	9
57	0	36	29	7	7
58	0	36	48	13	5
59	0	38	5	7	2
60	0	38	58	3	14
61	0	39	2	3	14
62	0	39	6	1	14
63	0	40	12	7	15
64	0	41	19	3	15
65	0	41	32	3	15
66	0	42	24	3	15
67	0	42	42	1	17
68	0	43	37	8	1
69	0	44	5	8	7
70	0	45	37	6	11
71	0	47	9	5	26
72	0	48	15	1	4
73	0	49	7	7	23
74	0	49	49	7	5
75	0	50	5	7	5
76	0	50	7	7	5
77	0	51	33	1	15
78	0	52	1	1	14
79	0	53	30	3	8
80	0	53	45	1	14
81	0	53	55	8	3
82	0	54	30	15	1
83	0	55	1	1	15
84	0	55	18	15	7
85	0	55	32	7	15
86	0	55	55	7	15
87	0	56	59	15	3
88	0	57	50	1	15
89	0	58	4	1	15
90	0	58	7	1	15
91	0	58	38	15	1
92	0	59	17	7	15
93	0	59	19	7	15
94	0	60	7	7	7
95	1	0	17	7	7
96	1	0	46	7	7
97	1	0	54	7	7
98	1	0	56	7	7
99	1	1	52	8	3
100	1	2	40	3	2

101	1	3	11	3	10
102	1	3	34	4	1
103	1	3	38	7	10
104	1	4	32	7	2
105	1	4	35	7	2
106	1	4	47	6	7
107	1	5	0	6	7
108	1	5	15	15	7
109	1	5	18	15	7
110	1	5	27	15	7
111	1	5	51	7	15
112	1	6	18	7	15
113	1	6	28	15	7
114	1	6	31	7	15
115	1	7	20	27	3
116	1	7	29	1	27
117	1	8	7	14	24
118	1	8	8	14	24
119	1	8	18	8	3
120	1	8	35	24	8
121	1	8	38	1	8
122	1	8	48	1	8
123	1	8	58	15	8
124	1	8	59	15	8
125	1	9	33	15	25
126	1	9	36	3	17
127	1	9	37	3	17
128	1	9	46	3	14
129	1	9	53	15	1
130	1	10	45	3	15
131	1	11	3	1	15
132	1	11	9	1	15
133	1	11	21	1	15
134	1	11	30	7	15
135	1	11	34	7	15
136	1	11	38	7	15
137	1	11	53	7	15
138	1	12	22	1	5
139	1	12	32	3	15
140	1	12	38	1	15
141	1	12	39	1	15
142	1	13	27	7	15
143	1	13	28	15	7
144	1	14	25	15	26
145	1	14	31	7	15
146	1	15	58	7	7
147	1	15	59	7	7
148	1	16	8	7	7
149	1	16	14	7	7
150	1	16	28	7	7
151	1	16	29	7	7
152	1	17	17	4	3
153	1	17	40	2	1
154	1	17	44	1	2

155	1	17	47	1	6
156	1	18	16	7	4
157	1	18	28	6	7
158	1	18	52	7	17
159	1	19	27	3	8
160	1	19	31	8	3
161	1	20	35	3	14
162	1	20	38	1	14
163	1	20	43	1	14
164	1	21	4	9	1
165	1	21	14	15	15
166	1	21	39	15	5
167	1	22	42	7	15
168	1	22	11	7	15
169	1	22	14	7	15
170	1	23	0	14	7
171	1	23	10	3	15
172	1	23	20	1	5
173	1	23	23	1	5
174	1	24	5	11	5
175	1	24	20	15	25
176	1	24	26	3	15
177	1	24	37	3	15
178	1	24	59	3	15
179	1	25	41	8	15
180	1	25	47	9	15
181	1	26	2	3	15
182	1	26	21	15	1
183	1	26	24	1	15
184	1	26	30	1	15
185	1	26	59	15	7
186	1	27	8	15	7
187	1	27	9	7	15
188	1	27	10	15	7
189	1	27	11	15	7
190	1	27	20	15	7
191	1	27	34	7	15
192	1	27	42	15	25
193	1	28	8	3	15
194	1	28	35	15	3
195	1	29	13	3	15
196	1	29	31	15	1
197	1	29	33	15	1
198	1	29	48	11	15
199	1	29	56	7	15
200	1	30	19	15	7

EXP.#22

	Time			Activity Observed			
	Hr.	Min.	Sec.	Obs.#1	Obs.#2	Obs.#3	Obs.#4
1	0	2	19	5	5	3	8
2	0	5	2	3	5	5	5
3	0	5	35	5	5	15	1
4	0	8	13	5	5	5	3
5	0	8	33	5	5	5	3
6	0	8	34	5	5	5	3
7	0	8	39	5	5	5	3
8	0	8	43	5	5	5	1
9	0	9	2	5	5	5	7
10	0	9	9	3	5	5	5
11	0	9	24	5	5	5	3
12	0	9	26	5	5	5	3
13	0	10	34	5	7	7	6
14	0	11	45	5	7	7	7
15	0	16	16	5	14	7	7
16	0	18	10	5	5	1	15
17	0	19	3	1	5	5	5
18	0	19	39	5	5	15	3
19	0	21	11	5	5	5	7
20	0	21	24	5	5	5	3
21	0	21	44	5	5	3	8
22	0	22	29	4	6	7	8
23	0	22	47	10	10	10	5
24	0	23	7	5	5	5	7
25	0	24	19	5	7	15	15
26	0	24	25	5	5	15	15
27	0	26	46	5	5	5	3
28	0	28	19	5	5	15	7
29	0	29	18	5	5	8	7
30	0	30	15	7	15	5	8
31	0	30	17	5	15	3	8
32	0	31	14	5	15	7	8
33	0	32	29	5	5	15	3
34	0	33	3	5	7	15	18
35	0	35	7	5	5	7	13
36	0	36	31	5	5	15	7
37	0	36	33	5	5	15	7
38	0	37	26	6	6	15	3
39	0	40	37	5	5	7	15
40	0	41	49	5	7	14	14
41	0	42	4	5	5	15	3
42	0	46	9	5	7	7	7
43	0	47	10	7	7	7	5
44	0	48	55	5	5	3	8
45	0	49	21	10	8	3	15
46	0	50	30	7	15	9	9

47	0	57	26	15	7	4	18
48	0	58	8	6	7	7	15
49	1	0	23	5	5	14	15
50	1	1	26	5	8	15	3
51	1	1	40	14	15	9	3
52	1	2	11	7	15	9	14
53	1	2	24	7	15	5	8
54	1	2	34	7	15	8	14
55	1	2	36	7	5	8	14
56	1	2	59	7	15	8	14
57	1	3	12	7	15	8	14
58	1	3	18	7	15	8	14
59	1	4	17	5	5	7	5
60	1	4	24	5	5	5	7
61	1	5	5	5	5	5	3
62	1	5	12	3	5	5	5
63	1	5	26	7	5	5	5
64	1	6	20	5	5	7	5
65	1	6	24	5	15	5	3
66	1	6	29	3	15	5	5
67	1	6	35	3	15	5	5
68	1	7	24	15	5	3	4
69	1	8	25	15	15	7	14
70	1	8	34	15	15	14	1
71	1	8	36	15	15	14	1
72	1	9	9	1	15	5	14
73	1	9	11	15	15	7	5
74	1	9	14	7	15	15	5
75	1	9	31	7	15	5	5
76	1	10	16	7	7	7	5
77	1	11	3	15	3	5	14
78	1	11	6	3	15	5	14
79	1	11	25	7	15	15	14
80	1	11	27	3	15	15	5
81	1	12	4	3	15	15	5
82	1	12	32	3	15	15	5
83	1	12	36	3	15	15	5
84	1	13	0	3	15	5	5
85	1	13	18	3	15	8	9
86	1	13	19	3	15	8	9
87	1	14	7	15	5	5	7
88	1	14	8	5	7	5	15
89	1	15	35	3	15	5	5
90	1	15	41	3	15	5	5
91	1	15	42	3	15	5	5
92	1	16	45	3	15	14	14
93	1	18	6	15	5	5	5
94	1	18	12	15	5	5	5
95	1	18	13	15	5	5	5
96	1	18	20	1	15	5	5
97	1	18	28	15	7	5	5
98	1	18	30	15	7	5	5
99	1	19	6	15	3	5	5
100	1	19	38	15	1	5	5

EXP.#29

	Time			Activity Observed	
	Hr.	Min.	Sec.	Obs.#1	Obs.#2
1	0	1	59	5	7
2	0	2	34	3	5
3	0	3	25	3	5
4	0	3	26	5	3
5	0	3	32	3	5
6	0	4	8	15	3
7	0	4	50	3	15
8	0	5	13	7	5
9	0	5	22	7	15
10	0	5	36	3	15
11	0	5	57	7	5
12	0	7	20	7	5
13	0	7	36	7	5
14	0	8	5	10	3
15	0	8	8	3	4
16	0	8	18	3	2
17	0	10	17	3	2
18	0	10	18	3	2
19	0	10	22	3	5
20	0	10	38	3	15
21	0	11	21	3	15
22	0	12	19	5	3
23	0	12	34	1	5
24	0	12	35	1	5
25	0	12	36	1	5
26	0	12	46	7	5
27	0	13	29	1	5
28	0	13	49	15	5
29	0	14	18	7	5
30	0	15	55	7	7
31	0	16	41	5	10
32	0	16	42	5	10
33	0	17	28	15	10
34	0	17	33	4	3
35	0	17	43	3	5
36	0	18	33	7	15
37	0	18	50	3	7
38	0	19	23	15	7
39	0	19	34	7	4
40	0	19	60	15	7
41	0	20	49	3	15
42	0	22	4	3	5
43	0	22	8	3	15
44	0	22	20	1	5
45	0	22	42	1	14
46	0	24	9	15	7

47	0	24	43	7	10
48	0	25	42	3	15
49	0	26	5	1	5
50	0	26	54	15	3
51	0	29	32	7	5
52	0	30	7	17	7
53	0	30	25	8	7
54	0	31	22	7	7
55	0	33	29	4	7
56	0	34	38	15	7
57	0	34	46	7	15
58	0	34	55	15	7
59	0	35	29	15	3
60	0	36	35	1	15
61	0	37	0	3	15
62	0	37	23	1	5
63	0	38	26	1	5
64	0	38	28	1	5
65	0	38	41	15	15
66	0	39	49	8	8
67	0	41	26	15	1
68	0	41	43	3	15
69	0	42	13	1	1
70	0	43	52	15	5
71	0	44	6	15	5
72	0	46	7	7	13
73	0	46	20	7	7
74	0	46	37	7	7
75	0	47	48	3	2
76	0	48	7	2	3
77	0	49	18	10	7
78	0	49	30	2	7
79	0	50	12	14	15
80	0	50	17	3	14
81	0	50	23	3	14
82	0	50	37	7	8
83	0	50	40	7	8
84	0	50	55	15	14
85	0	50	59	8	7
86	0	51	24	7	8
87	0	51	25	7	8
88	0	51	27	7	8
89	0	51	35	15	8
90	0	52	8	1	8
91	0	52	32	15	7
92	0	52	40	15	7
93	0	53	21	15	3
94	0	53	24	3	15
95	0	54	31	15	1
96	0	54	50	15	3
97	0	54	53	5	3
98	0	55	1	2	4
99	0	55	24	15	26
100	0	56	18	1	15

101	0	56	41	7	15
102	0	56	48	15	15
103	0	57	30	1	15
104	0	57	52	10	7
105	0	57	59	2	3
106	0	58	31	15	1
107	0	59	0	1	15
108	0	59	27	15	4
109	0	59	28	15	4
110	0	60	34	15	7
111	0	60	56	15	7
112	1	0	39	15	7
113	1	0	40	15	7
114	1	1	42	7	15
115	1	2	4	7	7
116	1	2	6	7	7
117	1	2	51	7	7
118	1	3	8	7	7
119	1	3	32	14	10
120	1	4	30	2	1
121	1	4	43	4	7
122	1	4	54	4	7
123	1	5	30	3	2
124	1	6	39	15	14
125	1	6	47	3	14
126	1	6	52	3	14
127	1	6	58	3	14
128	1	7	1	3	14
129	1	7	5	3	14
130	1	7	15	1	5
131	1	7	16	1	5
132	1	7	47	15	14
133	1	8	19	3	15
134	1	8	31	3	15
135	1	8	59	3	15
136	1	9	12	15	3
137	1	9	42	15	7
138	1	9	46	15	15
139	1	10	2	15	15
140	1	10	35	15	15
141	1	10	59	14	14
142	1	11	29	10	3
143	1	11	38	3	2
144	1	11	49	4	3
145	1	11	51	5	3
146	1	12	10	15	5
147	1	12	36	5	1
148	1	13	2	1	14
149	1	13	12	1	15
150	1	13	44	7	15
151	1	13	58	7	15
152	1	14	11	7	15
153	1	14	24	7	15
154	1	14	34	7	5

155	1	14	42	5	18
156	1	14	50	7	7
157	1	14	53	7	7
158	1	14	59	7	7
159	1	15	13	7	7
160	1	15	19	7	7
161	1	15	34	7	7
162	1	15	51	7	7
163	1	16	14	7	7
164	1	16	51	7	7
165	1	16	55	7	7
166	1	18	20	7	7
167	1	18	21	7	7
168	1	18	38	7	7
169	1	18	39	5	7
170	1	18	43	7	7
171	1	18	54	7	7
172	1	18	58	7	7
173	1	19	3	8	5
174	1	19	9	3	10
175	1	19	14	10	3
176	1	19	21	2	3
177	1	21	9	7	15
178	1	21	22	15	7
179	1	22	58	11	15
180	1	23	2	11	15
181	1	23	19	15	7
182	1	23	25	7	14
183	1	24	15	3	15
184	1	24	18	3	15
185	1	24	35	1	15
186	1	24	58	15	7
187	1	25	18	4	3
188	1	25	41	5	1
189	1	26	1	24	15
190	1	26	18	3	15
191	1	26	19	3	15
192	1	26	37	3	15
193	1	27	3	7	15
194	1	27	54	15	3
195	1	28	10	10	15
196	1	28	36	15	6
197	1	29	19	3	5
198	1	29	42	1	2
199	1	29	52	1	5
200	1	30	37	15	1

APPENDIX C

Table Of Probability To The Left Of Z -Value Of The Standard Normal Distribution

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998